

FEASIBILITY STUDY
I-77 from I-85 to Griffith Street

Mecklenburg County

Division 10

FS-0810B

Task Order No. 2
I-77 HOV-to-HOT Lanes Conversion

HOT Lanes Operations Plan

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1.0 INTRODUCTION

1.1 Purpose of Task Order No. 2

The purpose of Task Order No. 2 of the I-77 Feasibility Study was to analyze the feasibility of high-occupancy toll (HOT) operations along the corridor. The studied options included:

- Option 1 - convert the existing high-occupancy vehicle (HOV) lanes to HOT lane operations.
- Option 2 - convert the existing HOV facility to HOT lanes plus extend only the HOT lane from the current HOV facility terminus located south of Exit 23 (Gilead Road in Cornelius) to Griffith Street (SR-2158/ Exit 30 in Davidson).
- Option 3 - convert the existing HOV facility to HOT lanes plus add a HOT lane and a general purpose lane in each direction between the current HOV facility terminus near Exit 23 and Exit 30 as discussed above for Option 2.

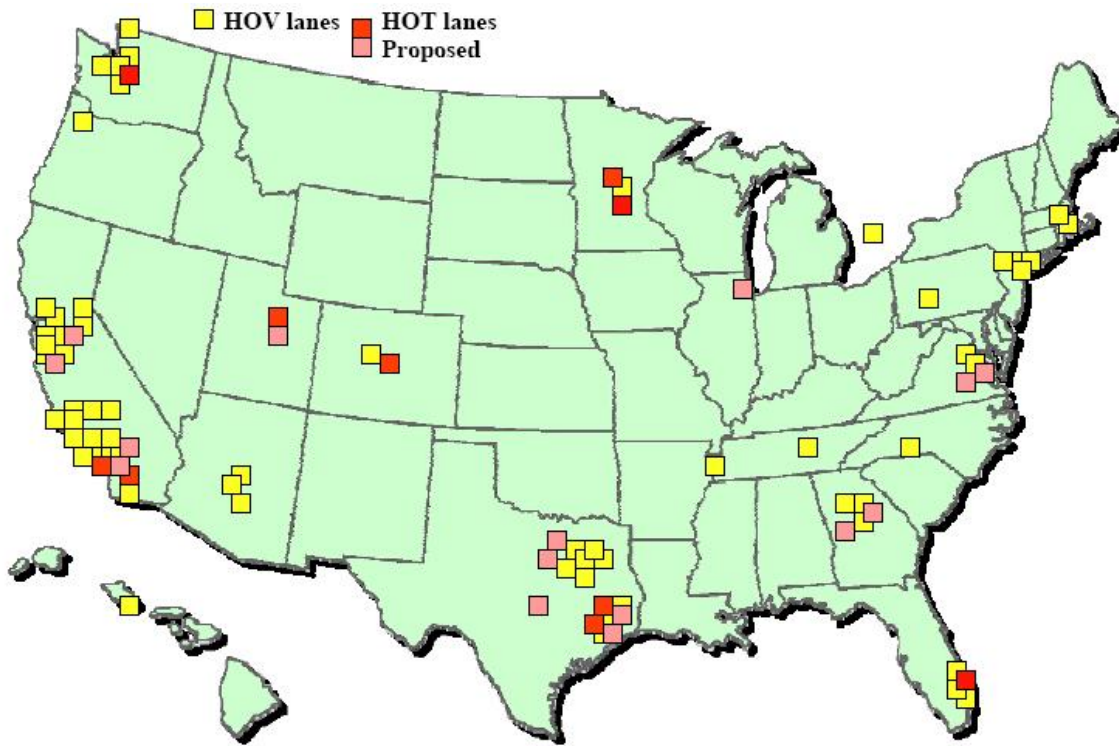
This task order identified issues, design modifications, revenue potential, benefits and costs associated with the aforementioned three alternatives.

1.2 National Context

In highly congested corridors where traditional strategies for improving mobility and roadway capacity cannot address unmet demand, specially-designated lanes are often implemented to more aggressively manage use of these lanes so as to improve roadway efficiency. This strategy provides a choice to motorists who otherwise would have to deal with traffic congestion. In the late 1960s, managed lanes began as restricted, often curbside lanes for buses on streets and a few expressways. By the mid-1970s, carpools and vanpools, usually with 3 or more persons, were allowed to use some dedicated lanes, which were termed HOV lanes. In the late-1980s, changes in federal policies allowed local governments to open HOV lanes to carpools with two or more persons. By the mid-1990s, congestion pricing was tested on several HOV lanes, and the term, "HOT lane", originated. There are currently over 3000 lane-miles of HOV or HOT lanes on freeways in North America plus a wide number of lanes primarily reserved for buses on arterials. Practically all HOV or HOT lanes are located in highly congested metropolitan areas where they provide a travel time advantage over adjacent lanes.

Figure 1-1 shows the urban areas in the United States where HOV and HOT lanes have been implemented/ considered.

Figure 1-1: HOV and HOT Lanes in the USA



1.2.1 HOV Lanes

Managed lanes over the past 30 years have generally been designated as HOV lanes with eligibility for carpools and vanpools. The following definition for HOV facilities explains the purpose of these facilities:

HOV Facility: A lane or roadway dedicated to the exclusive use of specific high-occupancy vehicles, including buses, carpools, vanpools or a combination thereof, for at least a portion of the day.

By offering a reserved lane for multi-person vehicles, HOV lanes emphasize *person movement* rather than traditional *vehicle movement*, thus improving the roadway's ability to move more people in fewer vehicles. This approach only works when an assured level of service in the HOV lane is preserved and time savings that encourage mode shifts to transit, vanpooling and carpooling are realized. To provide this benefit, the dedicated lanes are managed at a vehicle flow rate that is below traditionally defined lane capacity so that the lane does not become congested. HOV facilities enable transportation agencies to better manage freeway capacity and offer an alternative to congestion. When operated and managed at a high level of service, HOV lanes save peak-period travel time over adjacent mixed-flow lanes and have a theoretical capacity to move substantially more commuters than general use lanes during peak demand periods when priority must be assigned to the highest and best use. During these periods, HOV lanes provide significant benefits to those choosing to ride a bus or travel in a vanpool or carpool.

Figure 1-2: Example HOV Lane



The primary tools used to manage HOV lane use are eligibility and access. Eligibility restricts lane use to vehicles with a minimum number of persons traveling in each vehicle. Access has sometimes been restricted to specific access or egress points in order to manage demand and promote better traffic flow.

HOV lanes make the most sense when:

- Adjacent general-purpose lanes are heavily congested during peak periods.
- Sufficient demand exists among transit and rideshare users to justify a dedicated lane.
- Travel benefits are enough to cause solo commuters to shift to transit or ridesharing.
- Resources are limited for expanding roadway capacity to meet future demand conventionally.

Analysis of HOV lanes has shown that they can have a positive impact on corridor transit and rideshare use. Various before/after studies have shown that about 40 percent of HOV users come from previous carpoolers who have shifted from adjacent lanes or other routes into the HOV lane (called “spatial shifts”); another 40 percent are newly formed carpools and vanpools and transit riders who previously drove alone (called “mode shifts”); and the balance were new trips in the corridor often created because the dedicated lane provided a superior way of commuting.

1.2.2 HOT Lanes

In addition to the use of HOV lanes in managing roadway capacity, HOT lanes are being studied and implemented to further maximize the use of the limited roadway capacity plus generate revenue to partially pay for operations and maintenance of the facility. The following definition for HOT facilities explains the purpose of these facilities:

***HOT Facility:** A managed priced lane or roadway that gives preference to high-occupancy vehicles, including buses, carpools, vanpools or a combination thereof, and allow other vehicles (e.g. single-occupancy vehicles) that are willing to pay to use the facility for at least a portion of the day.*

By offering a reserved lane for multi-person vehicles and paying vehicles, HOT lanes not only emphasize *person movement* but also maximizing the use of available roadway capacity and generate revenue for reinvestment in the facility. This approach only works when an assured level of service in the HOT lane is preserved and time savings that encourage mode shifts to transit, vanpooling and carpooling are realized. To provide this benefit, the dedicated lanes are managed at a vehicle flow rate that is below traditionally defined lane capacity so that the lane does not become congested. HOT facilities enable transportation agencies to better manage freeway capacity and offer an alternative to congestion. When operated and managed at a high level of service, HOT lanes save peak-period travel time over adjacent mixed-flow lanes and have a theoretical capacity to move substantially more commuters than general use lanes during peak demand periods when priority must be assigned to the highest and best use. During these periods, HOT lanes provide significant benefits to those choosing to ride a bus, travel in a vanpool or carpool, and also to those that are willing to pay for a reliable travel time in the corridor.

Figure 1-3: Example HOT Lanes



The primary tools used to manage HOT lane use are eligibility, access, and tolls. Eligibility restricts lane use to vehicles with a minimum number of persons traveling in each vehicle. Access has sometimes been restricted to specific access or egress points in order to manage demand and promote better traffic flow. Type of toll operation and level of tolls are used to increase the use and managed the level of service of the HOT lanes.

HOT lanes make the most sense when:

- Adjacent general-purpose lanes are heavily congested during peak periods.
- There is not enough HOV demand to warrant for their exclusive use of the managed lane facility and thus has available managed lane capacity to add more vehicles – in other words, available capacity to sell and still maintain a high level of service.
- There is portion of solo commuters that place such a high value on their time that they are willing to pay to use the facility.

- Resources are limited for expanding roadway capacity to meet future demand conventionally.

Analysis of HOT lanes has shown that they can have a positive impact on the corridor for all commuters by providing more travel choices than the traditional HOV only operation. It not only benefits HOVs, and continues to encourage use of transit and rideshare, it also provides travel options to other users (e.g. solo drivers) that are willing to pay to use the facility. HOT lane operation also makes efficient use of limited roadway capacity and generates revenue to partially fund its operation and maintenance.

1.3 Managed Lanes Planning in the Charlotte Region

From 2007 to 2009, the North Carolina Department of Transportation (NCDOT) and local governments in the Charlotte region examined the existing and planned major highways throughout a 10-county area to identify where managed lanes could improve roadway capacity. The Charlotte Region *Fast Lanes* Study covered 12 primary corridors, totaling about 334 miles of freeways and arterials. The study used a two-phase process to determine which regional highways showed the greatest promise for managed lanes treatments. **Figure 1-4** indicates the corridors evaluated in this regional planning effort, highlighting those corridors, including I-77 North, which advanced into Phase 2.

1.3.1 Regional Goals and Objectives

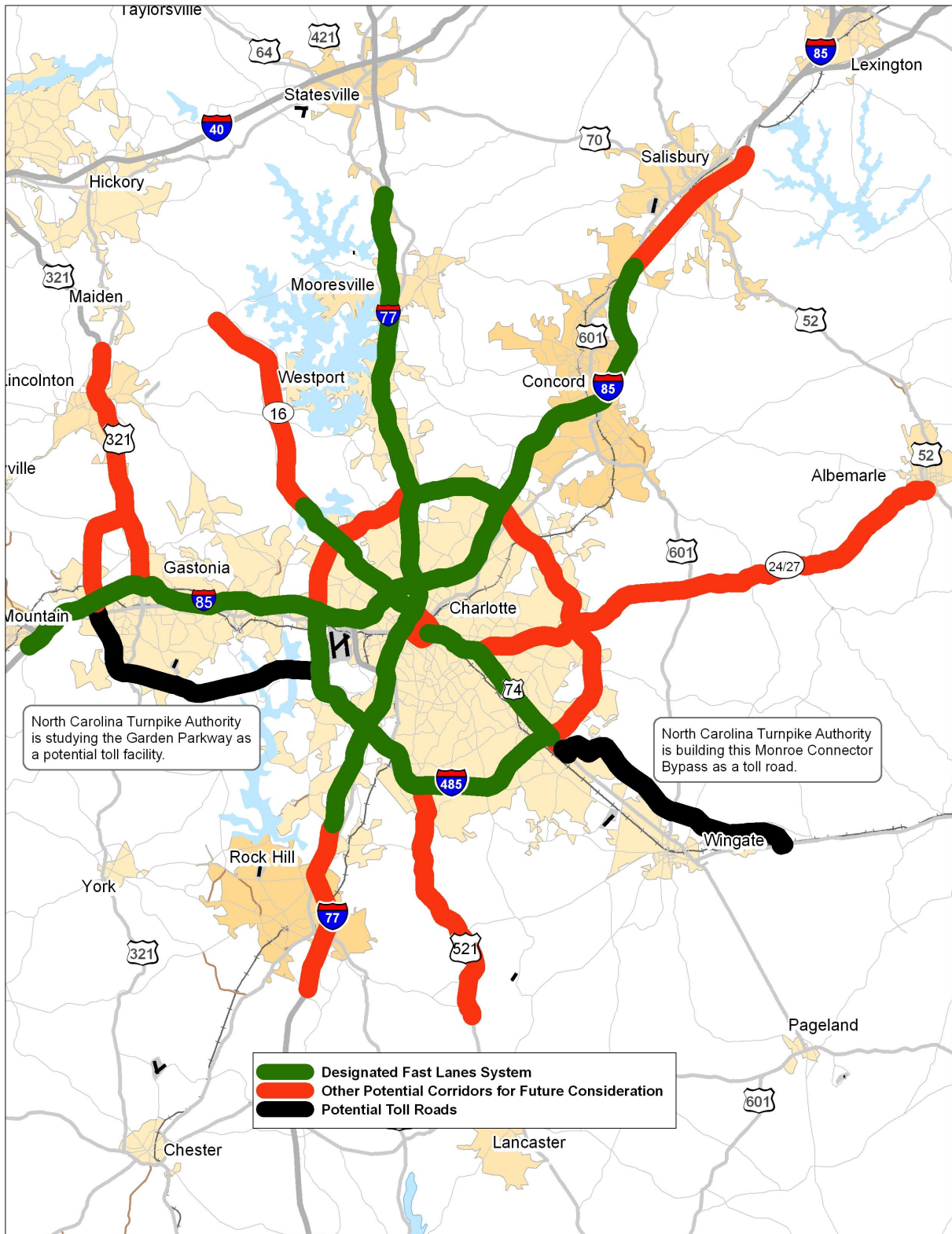
The Charlotte Region *Fast Lanes* Study identified the following goals for implementing managed lanes, such as HOV facilities:

- Maintaining mobility
- Improving roadway operation efficiency, safety and reliability
- Promoting transit and ridesharing
- Improving safety
- Providing travel options to meet user needs, such as “time-sensitive” travel, and
- Generating revenue to offset capital and operating expenses
- Improving air quality

Regional and/or corridor objectives for managed lanes include:

- Increasing person-moving capacity of the roadway
- Promoting transit and ridesharing mode split
- Optimizing vehicle-carrying capacity
- Promoting travel time savings, reliability, or efficiency for selected travel modes
- Promoting air quality by increasing ridesharing and transit as part of a conformity plan
- Increasing funding opportunities for new mobility improvements
- Enhancing existing transit investments and services in the region/corridor
- Providing a greater choice in serving multi-modal needs (people, goods, services)
- Improving the movement of commerce (goods and services movements)
- Supporting community land use and development goals, particularly to major areas of employment

Figure 1-4: Fast Lanes –Corridor Screening



Fundamental to these goals and objectives is an implicit set of conditions that should exist for HOV lanes to be considered viable. These conditions include the following:

- A recurring congestion problem with traffic operating at level of service D or worse within a corridor or region for a significant period of time each weekday
- A significant backlog of unmet travel demand, and/or lack of available resources (right-of-way, funding, regional consensus or environmental issues) to address capacity deficiencies in a more conventional means through adding roadway or transit capacity
- An interest and ability to minimally increase roadway capacity by managing its use to specific dedicated purposes to ensure that a high level of service can be provided as an alternative to recurring congestion

1.3.2 Conclusions for the I-77 North Corridor from Charlotte Region *Fast Lanes* Study

The travel demand for managed lanes in the I-77 North corridor, as shown in **Figure 1-5**, ranked near the top of corridors assessed in Phase 2 of the regional study. The forecasted travel time savings for managed lanes users in 2030 would exceed the industry rule-of-thumb of a half-minute per mile savings. These results were based on development of a regional managed lanes network. The *Fast Lanes* study concluded that I-77 North should be analyzed at the individual corridor level for managed lanes implementation.

1.4 I-77 HOT Facility Objectives

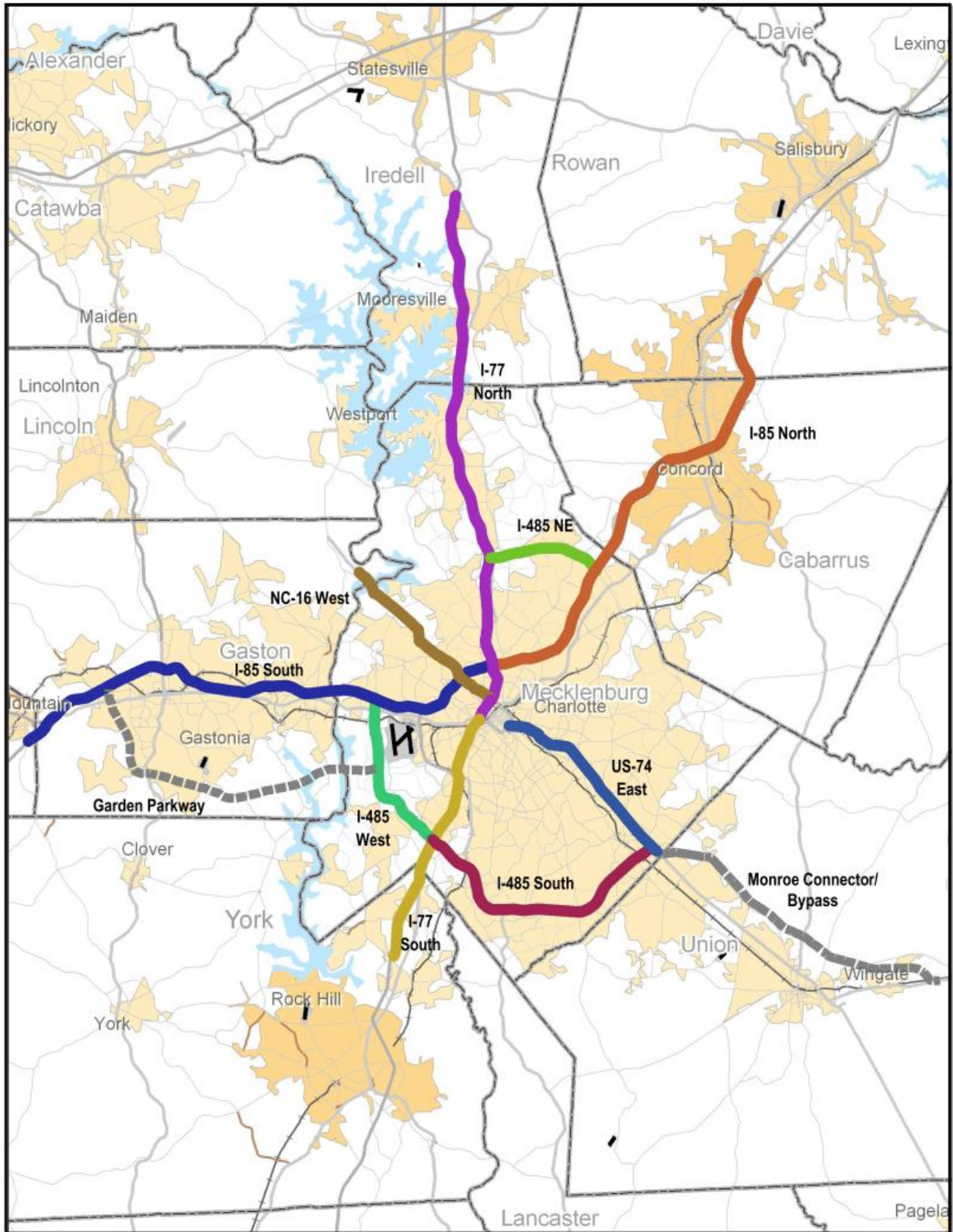
The objectives established in 2003 during the initial implementation of I-77 HOV lanes included:

- Move more people by increasing the number of persons per vehicle.
- Reduce travel time and ensure reliable trip times for HOVs using the I-77 managed lanes.
- Operate a safe HOV facility and not unduly impact the safety of the I-77 general purpose lanes.
- Maintain or improve public support for the I-77 HOV facility.

Based on the evaluation of the existing HOV lane against the objectives established in 2003 and the experience of other HOT lanes around the country, objectives for the proposed HOT lanes along I-77 are:

- ***Increase mobility in the I-77 corridor*** by moving more persons per vehicle and more vehicles than the number presently being carried in the HOV lanes while not impairing person movement.
- Reduce travel time and ensure reliable trip times for all eligible users for a HOT lane conversion of the I-77 HOV lanes.
- Operate a safe HOT lane facility and preserve the safety of the I-77 general purpose lanes.
- Test acceptance and maintain or improve public support for the I-77 HOT facility.
- Improve enforcement compliance.
- Demonstrate variable pricing as a means of improved lane management.

Figure 1-5: *Fast Lanes* – Phase 2 Corridor Evaluation



1.5 HOT Facility Enabling Legislation

General Statute 136-89.198 authorizes the North Carolina Turnpike Authority (NCTA), an operating division of NCDOT, to collect tolls on any existing interstate highway for which the United States Department of Transportation (USDOT) has granted permission by permit, or any other lawful means, to do so. According to the statute, the revenue generated from the collected tolls shall be used by the NCTA to repair and maintain the interstate on which the tolls were collected.

General Statute 136-89.210 to 136-89.218 establishes toll collection procedures for turnpike projects, including legal requirements for implementing open road tolling systems. The following sections cover various aspects of open road tolling:

- Section 136-89.213, administration of tolls and requirements for open road tolls.
- Section 136-89.214, bill for unpaid open road toll.
- Section 136-89.215, required action upon receiving bill for open road toll and processing fee for unpaid toll.
- Section 136-89.216, civil penalty for failure to pay open road toll.
- Section 136-89.217, vehicle registration renewal block for unpaid open road toll.
- Section 136-89.218, procedures for contesting liability for unpaid open road toll.

1.6 Organization and Content

This task order's report includes the following:

- Chapter 2 – Project Context – reviews the existing I-77 HOV lanes, identifies other proposed projects and plans for the corridor, and highlights current traffic management operations for I-77. The chapter also summarizes traffic projections for the general purpose lanes and HOT lane options and reviews current and forecasted deficiencies. This chapter reviews traffic estimates at the termini of the HOT lanes based on CORSIM simulation results.
- Chapter 3 – Agency Coordination – discusses coordination efforts among agency partners and their roles and responsibilities during the performance this Task Order No. 2.
- Chapter 4 – Facility Design and Access – describes the modifications and improvements at a conceptual level for extending the general purpose and/or HOT lanes north of Exit 23, Gilead Road. This chapter reviews elements such as design principles, typical section, signing and marking concepts, access, illumination, lane transitions and costs.
- Chapter 5 – Operations Policies – reviews eligibility policies, operating hours, access policies, pricing policies and any transition requirements to convert from the current HOV to HOT operations.
- Chapter 6 – Maintenance – identifies potential maintenance issues and responsibilities associated with the adding of general purpose and HOT lanes to I-77. This includes the tolling and enforcement systems, traffic control requirements and in-field maintenance related directly to HOT lane operations.

- Chapter 7 – Toll Collection and System Concept – provides an overview of the toll system, (configuration and subsystems) business rules for calculation of tolls, toll collection and signage procedure, and communications network, including issues related to interface with NCDOT's Metrolina Regional Traffic Management Center (MRTMC). The chapter also reviews enforcement needs and coordination with current incident management plans.
- Chapter 8 – Revenues – provides an estimate of potential revenue, including collection, allocation/ revenue sharing, and auditing process.
- Chapter 9 – Traffic Management – details requirements for interface with MRTMC, need for incident management and code enforcement. This chapter also includes provision for traffic management procedure for special events.
- Chapter 10 – Implementation Parameters – outlines possible timing of improvements based on interest and funding of NCDOT and local partners. This chapter includes transition of existing HOV lanes to HOT lanes and construction and delivery options.

2.0 PROJECT CONTEXT

This chapter reviews the design and operational features of conversion and extension of the existing I-77 HOV lanes opened by NCDOT in 2004. It also highlights existing traffic and transit operations along the corridor and summarizes traffic volumes and capacity deficiencies. Because there are no HOT lanes in operation in North Carolina, I-77 will be the first in the state if it is found to be feasible. HOT lanes are in operation or being developed in nearby states (Atlanta, Miami, northern Virginia) and being studied in Nashville.

2.1 Project History

In 2001, NCDOT began widening I-77 from its interchange with I-85 north to the proposed Charlotte Outer Loop (I-485). This project, known as I-3311A, involved widening the existing four-lane interstate facility to an eight-lane freeway. The project also included widening and strengthening the outside shoulders to meet current design standards and to accommodate traffic shifts during construction. A later project (I-3311B) was programmed to improve the section of I-77 from I-485 to NC-73 (Sam Furr Road).

Also in 2001, NCDOT completed the *I-77 Sub-Area Study*. This study analyzed the feasibility of including HOV lanes as the inside (median) lanes of project I-3311A, resulting in three general purpose lanes plus one HOV lane in each direction. Based on the recommendations of this study, the Mecklenburg-Union Metropolitan Planning Organization (MUMPO) added in January 2002 an HOV project along I-77 to the urban area's Immediate Project Needs list.

In 2002, the Federal Highway Administration (FHWA) approved an environmental document prepared by NCDOT that proposed designating two of the additional lanes constructed north of the I-85 interchange for HOVs. The HOV lane on southbound I-77 would extend from I-485 through the Brookshire Freeway (I-277) interchange (a total HOV lane length of 10 miles) while the northbound HOV lane would extend north of the I-85 interchange through W. T. Harris Boulevard (a total HOV lane length of about five miles).

In 2003, NCDOT approved HOV lane construction as an addition to the I-77 widening design-build project that was already underway. The HOV facility was opened in December 2004.

2.2 Existing HOV Facility Design and Operations

The current I-77 HOV facility consists of a concurrent flow lane located next to the median in each direction of the interstate. A diamond symbol used both in pavement markings and on overhead signs, designates the HOV facility. To ensure safety for all travelers, access into the HOV lanes is permitted at selected locations along the corridor. Those locations are designated by appropriate signing and a wide white skip line on the pavement. HOV signing also is included to identify these access areas. Double solid white pavement lines indicate where HOV lane access is prohibited. **Figure 2-1** and **Figure 2-2** show how pavement markings are used to designate facility access.

Figure 2-1: HOV Pavement Markings (no access)



Figure 2-2: HOV Pavement Markings (open access)



2.2.1 Southbound HOV Facility Access

HOVs traveling southbound are prohibited from accessing the HOV lane at two locations:

- At the beginning of HOV lanes near I-77's interchange with I-485
- Just north of the I-85 interchange, where the southbound I-77 HOV lane separates from the main roadway on its own ramp and rejoins I-85 further south. This connecting ramp provides HOVs the opportunity to bypass ramp traffic from I-85 (shown in **Figure 2-3**).
- The HOV lane ends south of the general purpose exit ramp for I-277 (Brookshire Freeway), a location where I-77 traffic volumes are lower, improving safety of the HOV merge into general purpose traffic lanes.

Figure 2-3: I-77 HOV Bypass of I-85 Interchange



2.2.2 Northbound HOV Facility Access

The northbound I-77 HOV lane begins ½-mile north of the I-85 interchange and ends at the I-485 interchange location, a distance of about 5 miles. The northbound freeway cross-section is three general-purpose lanes plus a concurrent flow HOV lane.

Designation of the median lane as an HOV lane begins far enough north of the I-77 entrance ramp from I-85 so that vehicles, particularly trucks, can safely merge from this lane into the leftmost general purpose lane. Eligible vehicles have continuous access to the northbound HOV lane until access is restricted just south of the I-77/Harris Boulevard interchange. The HOV designation for the northbound median lane extends beyond Harris Boulevard and is dropped prior to the I-485 interchange. The HOV lane becomes one of four general purpose lanes at this point, and this lane is dropped into two general purpose lanes in the vicinity of the I-485 interchange.

2.2.3 User Requirements

The current I-77 HOV facility is open to vehicles with two or more occupants with the following exceptions:

- **Motorcycles.** Federal law requires HOV lanes to be open to motorcycles regardless of the number of riders.
- **Emergency Vehicles.** The term “emergency vehicle” means any law enforcement, fire, police, or other government vehicle, and any public or privately owned ambulance or emergency service vehicle, when responding to an emergency.
- **Buses.** Any vehicle designed to transport 15 or more passengers, regardless of the actual number of occupants.

A motor vehicle with three or more axles, regardless of the number of occupants, is prohibited from using I-77 HOV lanes.

2.2.4 Hours of Operation

The I-77 HOV lanes are restricted to HOVs 24 hours a day, seven days a week. This determination was made to ensure safe operation of the HOV lanes, especially as the southbound HOV lane approaches the I-85 interchange. At this location, the HOV lane is carried over I-85 on a separate ramp and rejoins I-85 further south. This HOV ramp provides carpools, vanpools, transit vehicles, and emergency vehicles a bypass around I-85 traffic.

2.2.5 Enforcement

The North Carolina State Highway Patrol (NCSHP) randomly conducts enforcement along the I-77 HOV lanes in concert with normal enforcement duties. There have been no major issues associated with HOV lane enforcement. Motorcycle divisions of both NCSHP and Charlotte-Mecklenburg Police Department (CMPD) have the greatest involvement in lane enforcement because they can park on the inside shoulder. According to NCSHP personnel, a significant number of citations were initially issued because motorists claimed that they were unaware of occupancy requirement. But that has not been a problem for a while as HOV lane awareness as grown.

2.2.6 Performance Monitoring

A Performance Monitoring Plan was developed for the I-77 HOV facility in 2004 prior to its opening. The Plan’s purpose was to respond to HOV lane project objectives and track performance of the I-77 HOV operation in response to those objectives. Another purpose of performance monitoring is to fine-tune the facility’s operation, design, rules and regulations through a modest data collection effort. In 2006, a report was prepared to document the effectiveness and impacts of North Carolina’s first HOV lane project. Data was collected by various agencies both before and after the I-77 HOV facility was implemented. Information in this report was compared to baseline data collected in October 2004 to indicate how well the lanes were meeting approved objectives.

2.3 Other I-77 Corridor Projects or Plans

NCDOT’s Project No. I-3311B involves widening I-77 from the end of the current eight-lane section near I-485 to Exit 25 (NC-73 or Sam Furr Road). This project is not scheduled for

construction prior to 2015. This project extends the current Intelligent Transportation Systems (ITS) along I-77 north to Exit 25.

Augustalee, a major proposed mixed-use development in Cornelius, includes the widening on I-77 from four to six lanes from south of Exit 23 (Gilead Road) to Exit 28 (Catawba Avenue). On April 29, 2009, MUMPO amended the Transportation Improvement Program (TIP) to include I-77 widening related to the Augustalee project. MUMPO's approval of the TIP amendment included the preference that the new I-77 lanes be constructed as managed lanes. Another transportation improvement included in this new development is construction of a new interchange on I-77 at Westmoreland Road. The developer is currently preparing the required Interchange Justification Report (IJR) for approval by the FHWA and NCDOT.

In 2003, NCDOT completed a feasibility study for the proposed widening of I-77 from the I-3311B project, which ends at Exit 25 (NC-73) in Huntersville, to I-40 near Statesville in Iredell County. This study addressed interstate widening from the four-lane existing freeway to an eight-lane facility. NCDOT Division 10 staff also has analyzed adding one general purpose lane in each direction between the end of the existing widening at Exit 23 and Exit 30 by widening into the median. There is enough space in the median to accommodate this widening of the interstate.

NCDOT has two additional planning and environmental studies underway along I-77 south of I-85:

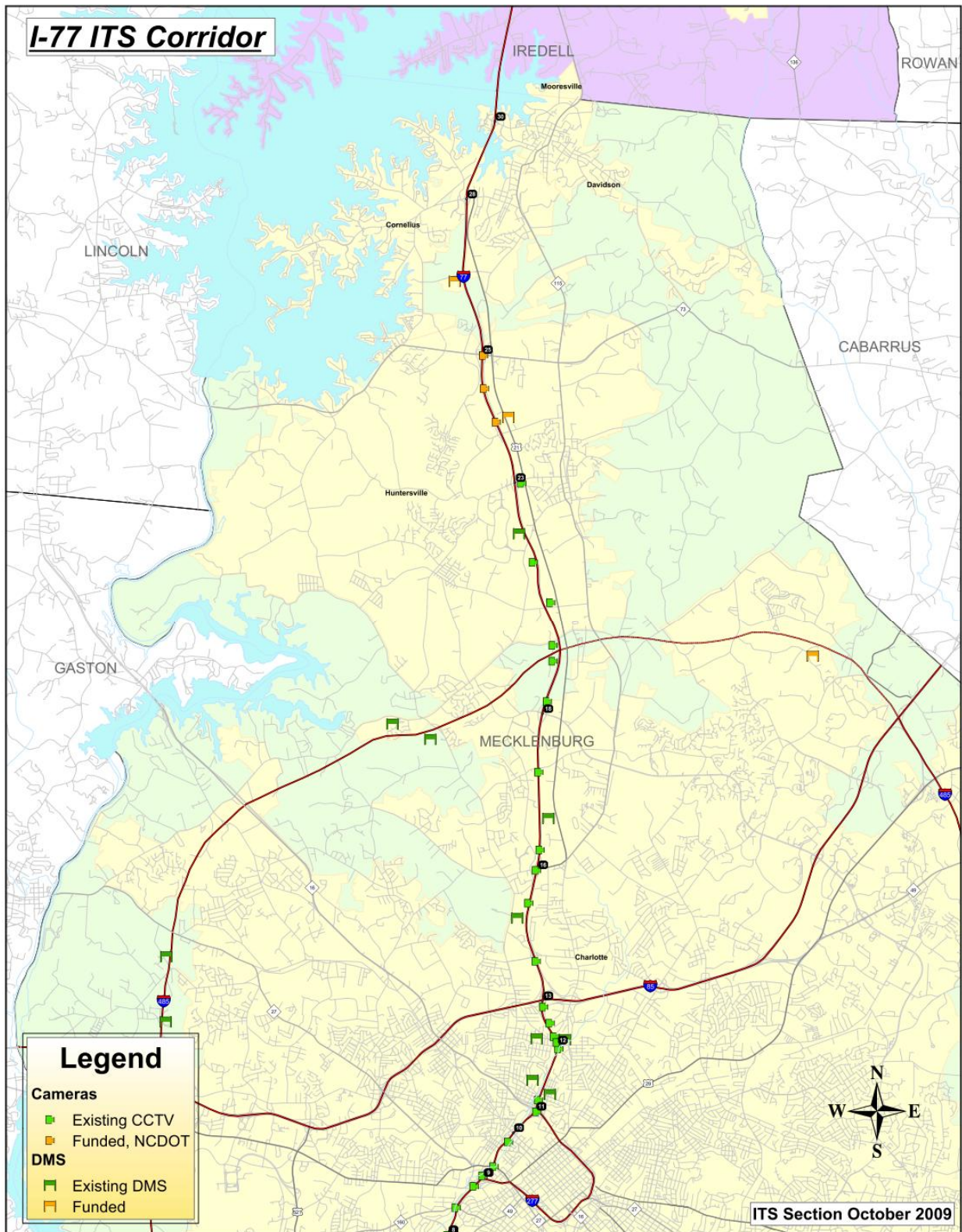
- Widening of lanes and shoulders between the I-77/I-85 interchange and I-277 (Brookshire Freeway) to re-establish full design standards for this freeway section. The southbound lanes and shoulders were reduced in 2004 to implement the HOV facility.
- Physical feasibility study for extending the I-77 HOV lanes between the I-77/I-85 interchange and Fifth Street in Center City Charlotte.

Charlotte Area Transit System (CATS) has completed planning and conceptual design of a commuter rail line between Mooresville and Center City Charlotte. Although this rapid transit line is parallel to I-77, it serves a different travel market and would not impact usage of the current HOV lanes or the potential facility extension and conversion to HOT lanes.

2.4 Traffic Operations and Management

NCDOT's MRTMC monitors and manages traffic along the existing I-77 HOV facility using closed circuit television (CCTV) surveillance, out-of-pavement traffic detectors and dynamic message signs (DMS). **Figure 2-4** identifies the location of existing and funded ITS features along I-77. The current HOV lanes do not have unique incident management needs or protocols within the MRTMC.

Figure 2-4: Existing ITS Features



2.5 Corridor Transit Operations

CATS currently operates four express bus routes along the I-77 HOV lanes (see **Figure 2-5**):

- **Route 48X, Huntersville Express.** Twelve AM peak period trips and 11 PM peak period trips on weekdays.
- **Route 53X, Northlake Express.** Four AM peak period trips and four PM peak period trips each weekday.
- **Route 77X, North Mecklenburg Express.** Seventeen morning trips and 18 afternoon/evening trips on weekdays.
- **Route 83X, Mooresville Express.** Four AM peak period trips and four PM peak period trips each weekday.

2.6 Traffic Operations

2.6.1 Existing and Future No-Build Traffic Volumes

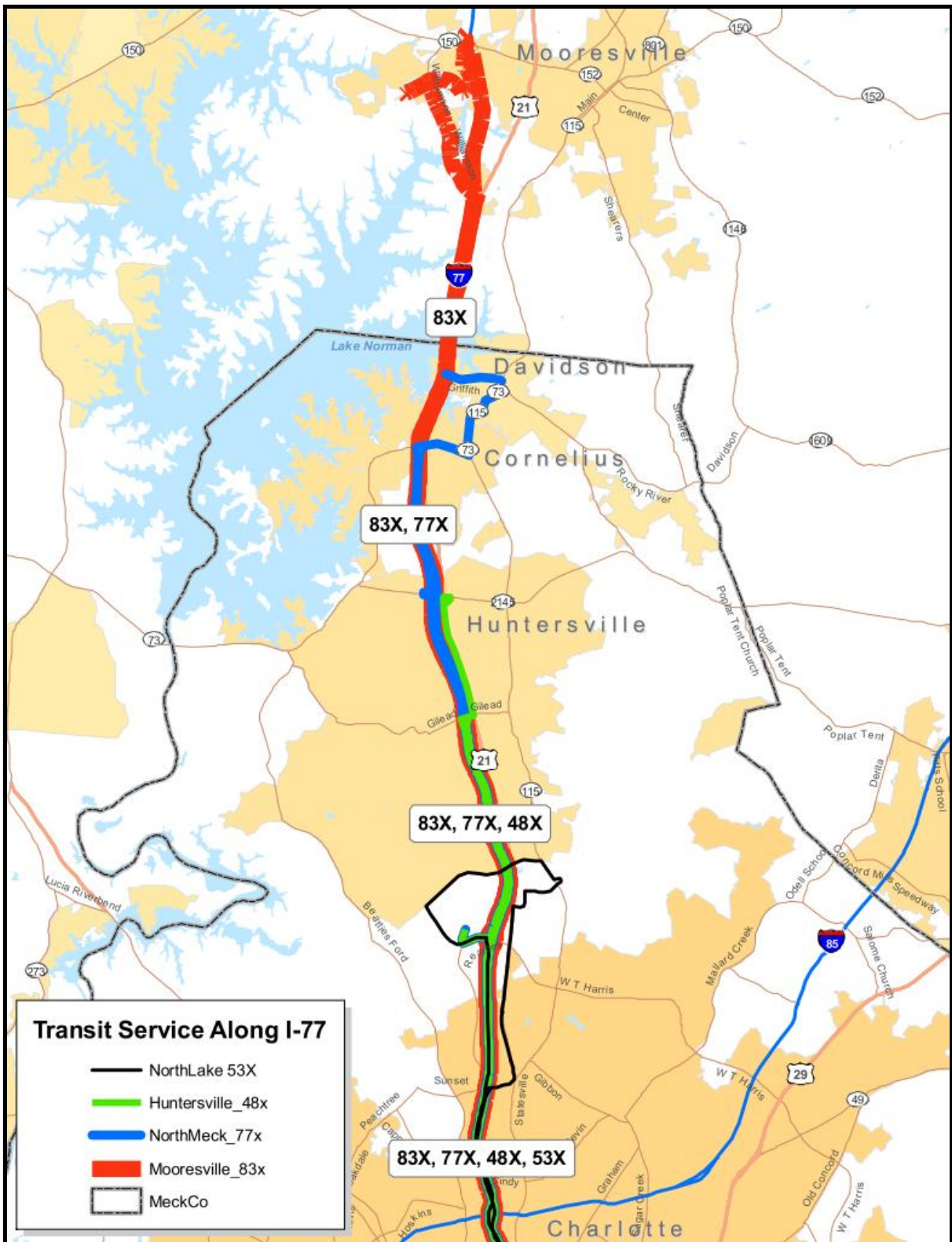
Table 2-1 shows a comparison of average annual daily traffic (AADT) volumes at key locations along the I-77 corridor. During the three years of available traffic count data, there was very little change in traffic volumes. In 2008, as a result of opening of I-485/I-77 interchange, traffic volumes along the corridor between I-85 and I-485 decreased between 3 to 5 percent. Traffic volumes south of I-85 grew at a very modest annual rate of less than 2 percent. **Table 2-1** also shows future traffic estimates from the regional travel demand model based on the approved long range transportation plan.

In general, the regional model's traffic forecast indicates that traffic volume along I-77 will continue to increase. The segment of I-77 south of I-85 appears to have reached capacity; therefore, there is little capacity to handle additional traffic. However, the northern section of I-77 between I-85 and the Iredell County line is estimated to experience significant traffic increases. In the short term (between 2008 and 2013), the northern section of the corridor is estimated to grow by more than 4 percent each year. In the long term (between 2008 and 2030), the northern section of the corridor is estimated to grow by about 2-3 percent annually.

Table 2-1: Comparison of Annual Average Daily Traffic (AADT) Volumes

	2006	2007	2008	2013 No-Build	2030 No-Build
South of Iredell/ Meck. CL	84,000	85,000	85,000	116,000	167,000
South of Westmoreland Road	87,000	84,000	81,000	116,000	133,000
North of Sunset Road	89,000	90,000	80,000	115,000	133,000
South of Sunset Road	113,000	115,000	106,000	132,000	152,000
South of I-85	151,000	152,000	155,000	156,000	177,000
South of Oaklawn Ave	163,000	164,000	169,000	170,000	180,000
1. 2006 through 2008 AADTs are based on NCDOT traffic counts. 2. 2013 and 2030 traffic forecasts are based on Metrolina Travel Demand Model results for a no-build scenario of the approved Long Range Transportation Plan.					

Figure 2-5: North Mecklenburg Existing Transit Routes



2.6.2 Future Traffic Volumes for HOT Lanes Build Alternatives

The traffic volumes for HOT lanes were estimated using a simplified mathematical model for projecting HOT lane demand and toll revenues. This sketch planning model estimated HOT lane volumes based on HOV lane volumes from the regional travel demand model.

The three HOT lane scenarios tested (see **Figure 2-6**) with the sketch planning model were:

- Option 1 - convert the existing HOV lanes to HOT lane operations.
- Option 2 - convert the existing HOV facility to HOT lanes plus extend only the HOT lane from the current HOV facility terminus located north of I-485 to Catawba Avenue (Exit 28 in Cornelius).
- Option 3 - convert the existing HOV facility to HOT lanes plus add a HOT lane and a general purpose lane in each direction between the current HOV facility terminus north of I-485 and Exit 30.

Figure 2-6: HOT Lane Scenario Option

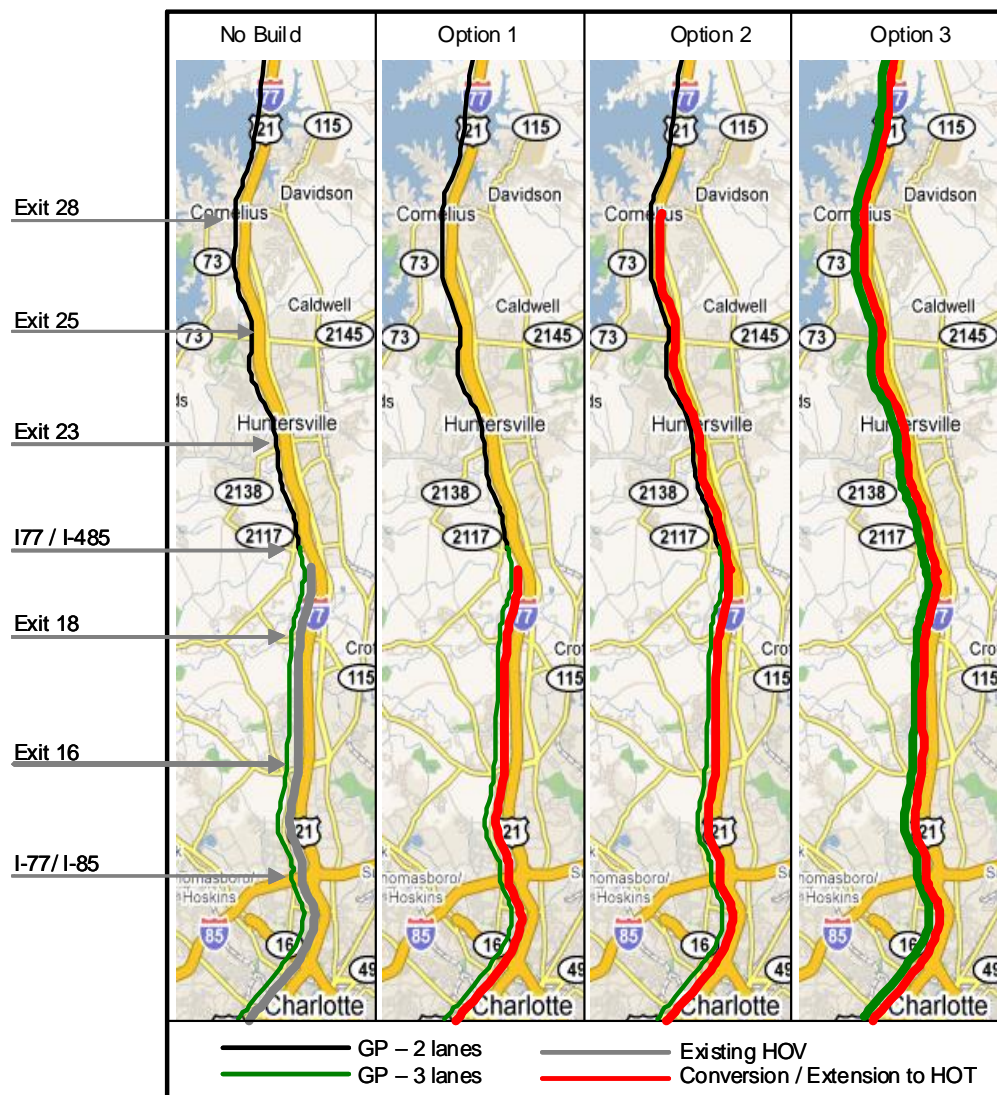
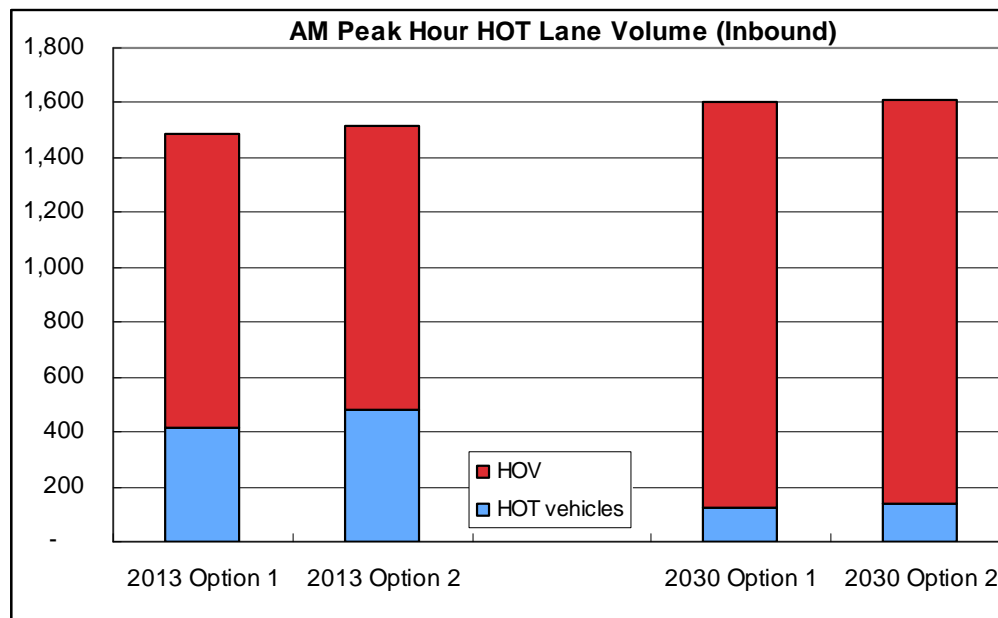


Figure 2-7 shows volume estimates in the proposed HOT lanes from the simplified mathematical model. There would be more vehicles in the HOT lane under Option 2 in both planning years. The figure also indicates that there is higher percentage of toll paying vehicles in 2013 (30 percent) when compared to 2030 (8 percent). In 2013 there is enough capacity available to sell in the HOT lane and there is enough demand and willingness to pay the toll to use the facility. Although there is similar demand and willingness to pay toll in 2030, there is nearly as much capacity to sell and maintain the high level of service. Therefore, the HOT lane has fewer toll paying vehicles in 2030. Given the high demand for HOT lane use in 2030, the HOV policy allowing free use for vehicles with two or more occupants should be re-visited to consider restricting free use to vehicles with three or more occupants.

Figure 2-7: AM Peak Hour (southbound) volume in HOT Lane



2.7 Traffic Operational Analysis

2.7.1 Methodology

Task Order No. 2 included traffic simulation along a freeway network consisting of the segment of I-77 between La Salle Street (Exit 12) and Griffith Street (Exit 30) and the portion of I-85 between Beatties Ford Road (Exit 37) and Statesville Road (Exit 39). The traffic simulation and analysis package used for the analysis was CORSIM, which was developed for the FHWA. CORSIM has the capability to analyze traffic flows on both freeways and surface street systems and to indicate the effects of additional lanes, transit service, accidents, and on-street parking.

As shown in **Figure 2-6**, there were three HOT lanes options analyzed as part of this task order. The CORSIM simulation package was used to:

- Assess the impact of HOV-to-HOT lanes conversion of the existing facility as well as the extension of HOT lanes through Catawba Avenue (Exit 28 in Option 2) and Griffith Street (Exit 30 in Option 3) on freeway operations
- Assess the system impacts on a comprehensive scale
- Determine freeway residual impacts, if any, resulting from the proposed freeway modifications

The CORSIM network for Task Order No. 2 was prepared from the base existing conditions network. Using the existing network, the current HOV facility was converted to HOT lanes to create Option 1. Under Option 2, the converted HOT lane was extended to Catawba Avenue (Exit 28). In Option 3, a HOT lane plus another general purpose lane was added through Griffith Street (Exit 30) in the northbound and southbound directions. The volumes for the three options were estimated using results from the Metrolina Regional Travel Demand Model. Traffic analysis was performed for the planning years of 2013 and 2030 for AM and PM peak hour conditions.

2.7.2 Results and Analysis

Option 1 - Conversion of Existing HOV facility to HOT Lanes

2013 AM Peak Hour (Southbound) - Based on a comparison to no-build conditions, the level of service along I-77 would improve slightly following the HOV-to-HOT lanes conversion. Average speeds along I-77 would increase from 42 miles per hour (mph) to 44 mph while overall delay for vehicles traveling along the freeway would decrease from 47 minutes to 43 minutes, a 9 percent improvement.

2013 PM Peak Hour (Northbound) - The level of service along I-77 would once again improve slightly following the HOV-to-HOT lanes conversion. Average speeds along I-77 would increase from 44 mph to 46 mph while overall delay for vehicles traveling along the freeway would decrease from 51 minutes to 47 minutes, an 8 percent improvement.

2030 AM Peak Hour (Southbound) - Based on a comparison to no-build conditions, the level of service along I-77 would improve slightly following the HOV-to-HOT lanes conversion. Average speeds along I-77 would increase from 35 mph to 39 mph while overall delay for vehicles traveling along the freeway will decrease from 80 minutes to 67 minutes, a 16 percent improvement.

2030 PM Peak Hour (Northbound) - The level of service along I-77 would once again improve slightly following the HOV-to-HOT lanes conversion. Average speed along I-77 would increase from 44 mph to 46 mph while overall delay for vehicles traveling along the freeway would decrease from 58 minutes to 53 minutes, a 9 percent improvement.

Option 2 - HOV-to-HOT Lanes Conversion and HOT Lane Extension

2013 AM Peak Hour (Southbound) - When compared to No-Build conditions, the level of service will improve by two grades for southbound operations along I-77 between LaSalle Street and Catawba Avenue. The level of service would improve from a level of service “F”

to a level of service “D” for not only on and off ramp locations but also mainline southbound freeway operations.

The average speed along I-77 would improve by 9 mph, from 42 mph to 51 mph. Overall vehicular delay time will decrease from 47 minutes to 31 minutes, a reduction of over 16 minutes (34 percent improvement) for vehicles traveling along I-77.

2013 PM Peak Hour (Northbound) - The level of service for I-77 northbound operations will also improve by two levels when compared to No-Build conditions. Once again, the level of service would improve from a level of service “F” to a level of service “D” for not only ramp locations but also mainline northbound freeway operations.

Average travel speeds would improve by 9 mph, from 44 mph to 53 mph. Overall vehicular delay time will decrease from 51 minutes to 31 minutes, a drop of 20 minutes (39 percent reduction) for vehicles using I-77.

2030 AM Peak Hour (Southbound) - When compared to No-Build conditions, the level of service will improve by a two levels for southbound operations along I-77 between LaSalle Street and Catawba Avenue. The level of service improves from a level of service “F” to a level of service “D” not only at ramp locations but also for mainline southbound freeway operations.

Overall I-77 speeds would increase by 16 mph, from 35 mph to 51 mph. Overall vehicular delay time will decrease from 80 minutes to 34 minutes, a reduction of 46 minutes (58 percent reduction) for I-77 motorists.

2030 PM Peak Hour (Northbound) - The level of service for I-77 northbound operations will again improve by two levels when compared to No-Build conditions. Similar to the CORSIM results for 2013 operations, the level of service improves from a level of service “F” to a level of service “D” not only at on and off ramp locations but also for mainline northbound freeway operations.

Average speeds along I-77 would improve by 5 mph, from 44 mph to 49 mph. Overall vehicular delay time will decrease from 58 minutes to 42 minutes, about 16 minutes less representing a 28 percent reduction for I-77 travelers.

Option 3 - HOV-to-HOT Lanes Conversion Plus Extension of HOT Lanes and Addition of General Purpose Lanes

2013 AM Peak Hour (Southbound) - When compared to No-Build conditions, the level of service is projected to improve by three levels for southbound operations along I-77. The level of service would improve from a level of service “F” to a level of service “C” at on and off ramp locations and for mainline southbound freeway operations.

The average speed along I-77 will improve by 7 mph, from 42 mph to 49 mph. Overall vehicular delay time would decrease from 47 minutes to 35 minutes, a reduction of 12 minutes, representing a 25 percent improvement, for all vehicles traveling along I-77.

2013 PM Peak Hour (Northbound) - The level of service for northbound operations would improve by three levels along the I-77 section between LaSalle and Griffith Streets when compared to No-Build conditions. The level of service improves from a level of service “F” to

a level of service “C” not only at ramp locations but also for mainline northbound freeway operations.

Average I-77 speeds are forecasted to improve by 14 mph, from 44 mph to 58 mph. Overall vehicular delay time decreased from 51 minutes to 20 minutes, a drop of over 31 minutes (61 percent reduction) for vehicles using I-77.

2030 AM Peak Hour (Southbound) - When compared to No-Build conditions, the level of service is projected to improve by two grades for I-77 southbound operations. The level of service improves from a level of service “F” to a level of service “C” for both ramp locations and for mainline operations.

The average speed along I-77 would improve by 25 mph, from 35 mph to 60 mph. Overall vehicular delay time is shown to decrease from 80 minutes to 20 minutes, a one-hour reduction of 60 minutes for I-77 motorists.

2030 PM Peak Hour (Northbound) - The level of service for I-77 northbound operations would improve by three levels when compared to No-Build conditions. The level of service is projected to improve from a level of service “F” to a level of service “C” at ramp locations and for mainline operations.

The overall travel speed will improve by 7 mph, from 44 mph to 51 mph. Overall vehicular delay time will decrease from 58 minutes to 36 minutes, 22 minutes less representing a 38 percent reduction for I-77 travelers.

2.7.3 Recommendations/Comparative Analysis

Option 1 – HOV-to-HOT Lanes Conversion Only

Based on CORSIM analysis results, traffic operations would improve on I-77 during both peak periods in 2013 and 2030. Although the analysis indicates that there is only a small increase in average travel speeds (two miles per hour), the key finding is that the conversion from HOV to HOT operation is feasible and will not have a negative impact on levels of service on the managed lanes or the general purpose lanes.

Option 2 – HOV-to-HOT Facility Conversion and Extension

Based on CORSIM analysis results, designation of the proposed HOT lane would end about ½-mile south of Exit 28. Traffic in the northbound general purpose lanes would merge to the leftmost lane ensuring that HOT lanes users have priority when three northbound lanes are reduced to two lanes. The outside general purpose lane would drop at the exit ramp at Catawba Avenue (Exit 28).

The southbound HOT lane would begin south of the causeway between Exits 28 and 30.

Option 3 – HOT Lane Extension and General Purpose Lane Addition

The CORSIM analysis for adding two lanes (one HOT lane and one general purpose lane) in each direction to I-77 indicated a need to widen the I-77 causeway between Griffith Street (Exit 30) and Langtree Road (Exit 31) in order to prevent a bottleneck from merging traffic in the afternoon peak period where the northbound HOT lane ends. HOT lane designation would end just north of Exit 30 but the new lane would continue north as a general purpose

lane. One general purpose lane would drop at the off ramp at Exit 28, resulting in I-77 having three northbound lanes to Langtree Road (Exit 31) where another general purpose lane would end at this recently-completed interchange.

Comparative Analysis

Table 2-2 lists the key operational improvements of Option 2 and Option 3 when compared to the No-Build option. The results shown in the table are typical benefits for the corridor. For example, the travel time savings are between Exit 30 (Griffith Street) and Exit 19 (I-485). The level of service measure is also an average based on critical locations (for example south of Exit 28 (Catawba Avenue) and Exit 25 (NC-73). Both build options show improvements in travel time as a result of reduced congestion and improved levels of service from “F” to “C/D”. As expected, Option 3 results in a better level of service as a result of providing three general-purpose lanes in addition to the HOT lane. Option 1 is not included in the table because it involved simple conversion of the existing HOV lane.

Table 2-2: Comparative Analysis

Task Order No. 2, I-77HOV/ HOT Conversion												
Alt. Description	2013						2030					
	AM (Southbound)			PM (Northbound)			AM (Southbound)			PM (Northbound)		
	Speed	Travel Time	LOS	Speed	Travel Time	LOS	Speed	Travel Time	LOS	Speed	Travel Time	LOS
No - Build	18	33	F	35	24	F	16	36	F	28	30	F
Option - 2 (3- Lane section)	58	12	D	58	12	D	55	13	D	58	12	E
Option - 3 (4- Lane section)	62	10	C	60	10	C	60	10	D	62	10	C

3.0 AGENCY COORDINATION

The following federal, state and local agencies were involved in the work activities of Task Order No. 2 of the I-77 Feasibility Study:

- **NCDOT.** The agency is the owner, designer and operator of I-77 and directed Task Order No. 2 through the Feasibility Studies Unit of its Planning and Programming Branch. Staff members from various NCDOT branches and units participated in this planning project. NCDOT's MRTMC manages traffic operations along I-77, including response to traffic incidents and special events. NCDOT's Incident Management Assistance Patrol (IMAP) provides assistance to motorists involved in traffic accidents or vehicle break-downs. NCTA is the operating division of NCDOT that is authorized to collect tolls on turnpike projects.
- **FHWA.** If the State chose to implement pricing on the I-77 HOV facility, it must execute a Title 23 United States Code (U.S.C.) Section 166 toll agreement with the FHWA. The federal agency has developed a model agreement which must be executed. NCDOT must submit a proposal for FHWA review and approval that addresses the following elements before HOT vehicles can use a HOV facility:
 - Presence of a program that addresses how a motorist can enroll and participate in a toll program.
 - Implementation of a system that will automatically collect the tolls, or indicate that a system will be implemented in a reasonable period of time following HOT lane establishment.
 - Policies and procedures to manage demand for the facility by varying the toll amount, if necessary to ensure acceptable performance.
- **NCSHP.** This state department is the primary enforcement agency for the current I-77 HOV lanes, and it has been identified by the NCTA as the agency responsible for enforcement along toll facilities.
- **City of Charlotte.** The Charlotte Department of Transportation (CDOT) partners with NCDOT in highway operations and supports HOV-to-HOT facility implementation. CDOT played a significant role in the opening of the I-77 HOV lanes in 2004. Departmental staff provided input to the Operations Plan and served as the liaison with offices of the Mecklenburg County District Attorney and local judges. CATS operates vanpools and express bus service along the I-77 HOV lanes. The agency also oversees the region's Transportation Demand Management (TDM) program, which includes a ride matching program to increase carpooling. The City's Police Department assists NCSHP in HOV lane enforcement.

3.1 Coordination during Task Order No. 2

Throughout Task Order No. 2, a technical team provided input on study results and recommendations. The Technical Study Committee (TSC) consisted of representatives of the following agencies:

- NCDOT
- FHWA
- CDOT

The TSC met during the task order to review progress, discuss preliminary recommendations and offer suggestions. Technical committee members also served as study liaisons to their respective agencies.

4.0 FACILITY DESIGN AND ACCESS

This chapter describes the design features of the potential conversion of the I-77 HOV facility to HOT lanes and their extension to Exit 30 in the Town of Davidson. As stated in Chapter 1.0, Task Order No. 2 examined the following three options:

- Option 1 - convert the existing HOV lanes to HOT lane operations.
- Option 2 - convert the existing HOV facility to HOT lanes plus extend only the HOT lane from the current HOV facility terminus located south of Exit 23 (Gilead Road in Cornelius) to Griffith Street (SR-2158/ Exit 30 in Davidson).
- Option 3 - convert the existing HOV facility to HOT lanes plus add a HOT lane and a general purpose lane in each direction between the current HOV facility terminus near Exit 23 and Exit 30 as discussed above for Option 2.

4.1 Design Principles for HOT Lanes Facility

The design principles used in the I-77 HOV-to-HOT lanes conversion are similar to those employed along the existing facility south of I-485 as well as HOT lanes conversions in other locations around the country.

4.2 Typical Section

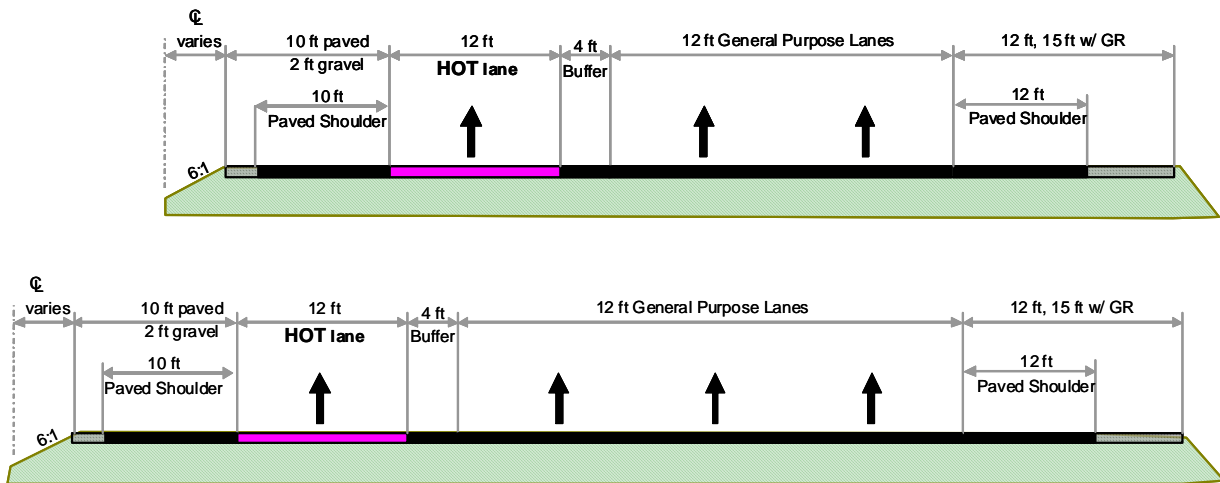
The HOT and general purpose lanes would be 12-feet wide with a 4-foot painted buffer between the HOT and general purpose lanes. The inside (left) paved shoulder width would be 10 feet while the outside (right) paved shoulder width would be 12 feet. No reductions from full design widths would be necessary. **Figure 4-1** shows the typical sections for both build options.

Plastic tubes or pylons would not be used in the buffer area to separate the HOT lanes from general purpose lanes because of maintenance costs and close proximity to high-speed traffic. A minimum 1000-foot per lane weave distance for each general purpose lane would be applied between right-side ramps and HOT lanes weave areas. Vehicle detection would be provided from the side of the facility or overhead.

4.3 Trade-offs in Accommodating Design Principles

Safety is a major consideration when evaluating HOT lane facility design elements. The available right-of-way and median of I-77 generally allow for all desirable design components to be included. These features include 12-foot lane widths, inside breakdown shoulders and buffer separation to address the potential speed differential between HOT and general purpose lanes. NCSHP and Charlotte police officers have safely used the 10-foot inside shoulder for enforcement purposes since the HOV lanes opened in 2004. In isolated segments, particularly on the south end of the corridor, design exceptions are currently in effect. Pre-existing trade-offs made when the HOV lane was implemented between I-85 and Brookshire Boulevard (I-277) include narrower lanes, no buffer separation and a narrower inside shoulder. These trade-offs were deemed to be acceptable until such time that widening could be undertaken to return lane and shoulder widths to full standards.

Figure 4-1: Typical HOT Lane Cross Section

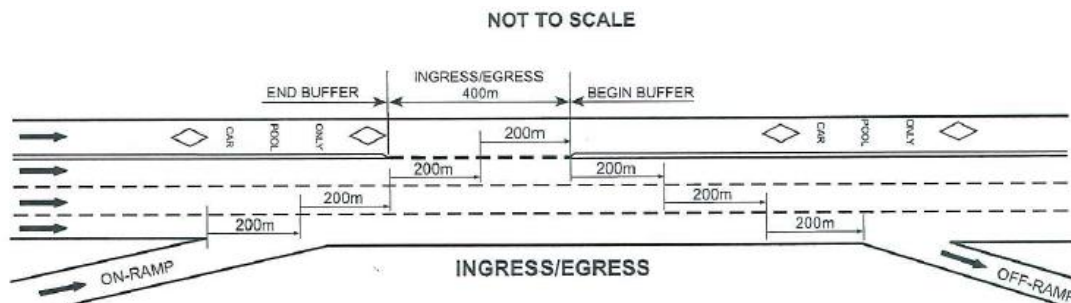


4.4 Access and Termini Treatments

Intermediate access with the HOT lanes would be similar to the approach taken for the HOV lanes. Motorists would be permitted to enter and exit the HOT lane only at designated breaks in the solid pavement markings. These locations coincide with operational settings that match major ingress and egress demand to and from right side ramps, and located to allow for a minimum of 600 feet and desirably 1000 feet per general purpose lane for merging and weaving between the left and right sides (**Figure 4-2**). Intermediate access would be spaced about every two to three miles. The length of the intermediate access may vary based on anticipated demand, but should be considered to be about 1500 feet in length and no less than 1200 feet.

Termini treatments at either end attempt to match the merging demand with other traffic movements such that no level-of-service reductions occur. CORSIM modeling was performed on current and forecast-year traffic volumes to define the best way of handling the project termini assuming a fully loaded lane. The Metrolina Travel Demand Model was used to project future year demand for specific access movements.

Figure 4-2: Typical Weave Criteria for Intermediate Access Locations

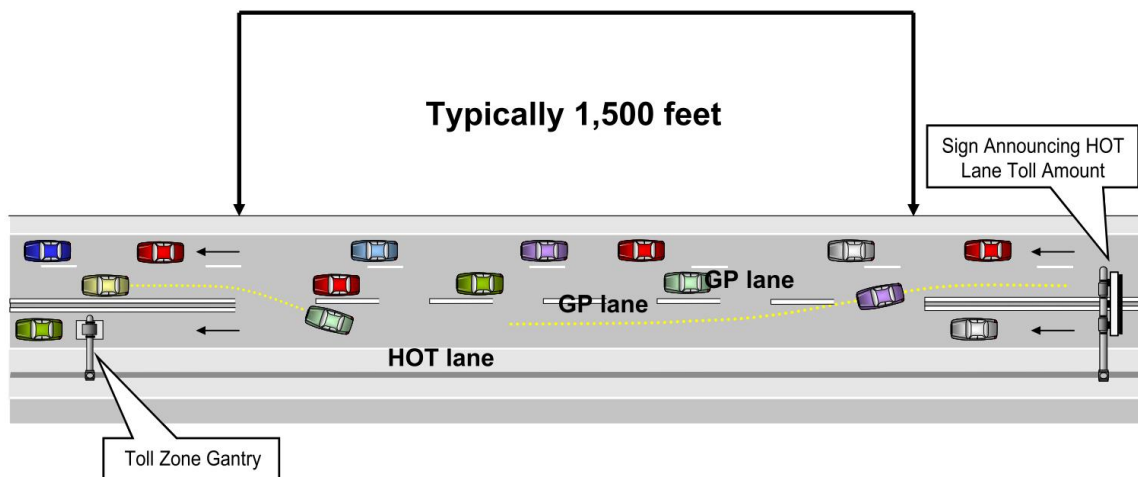


4.5 Signing and Pavement Markings

HOT lanes signing would be changed from current conditions to reflect the latest federal rulemaking. As such, the HOV sign and pavement marking diamonds would be removed, and the facility would be called “Express Lanes.” Regulatory signing would continue to be black on white, with guide signing white on green. Banners would be applied to all “Express Lane” signing to distinguish communication to these users from general traffic. Example signing is shown in **Figure 4-4**.

In the vicinity of an intermediate access, advance signing would indicate an upcoming access at one mile and half-mile intervals. **Figure 4-3** shows the sequence of signs within the access zone, reflecting traffic moving from right to left. A sign displaying the prevailing toll rate for up to two Center City destinations would be located immediately upstream of the access opening. Beyond the access opening, a toll gantry would record the transaction. Just beyond the toll gantry, a sign would display downstream exits and approximate mileage. Each access opening would facilitate both ingress and egress movements with the HOT lane. Regulations would restrict access except at designated openings, as is now the case on the I-77 HOV lanes.

Figure 4-3: Typical Intermediate Access

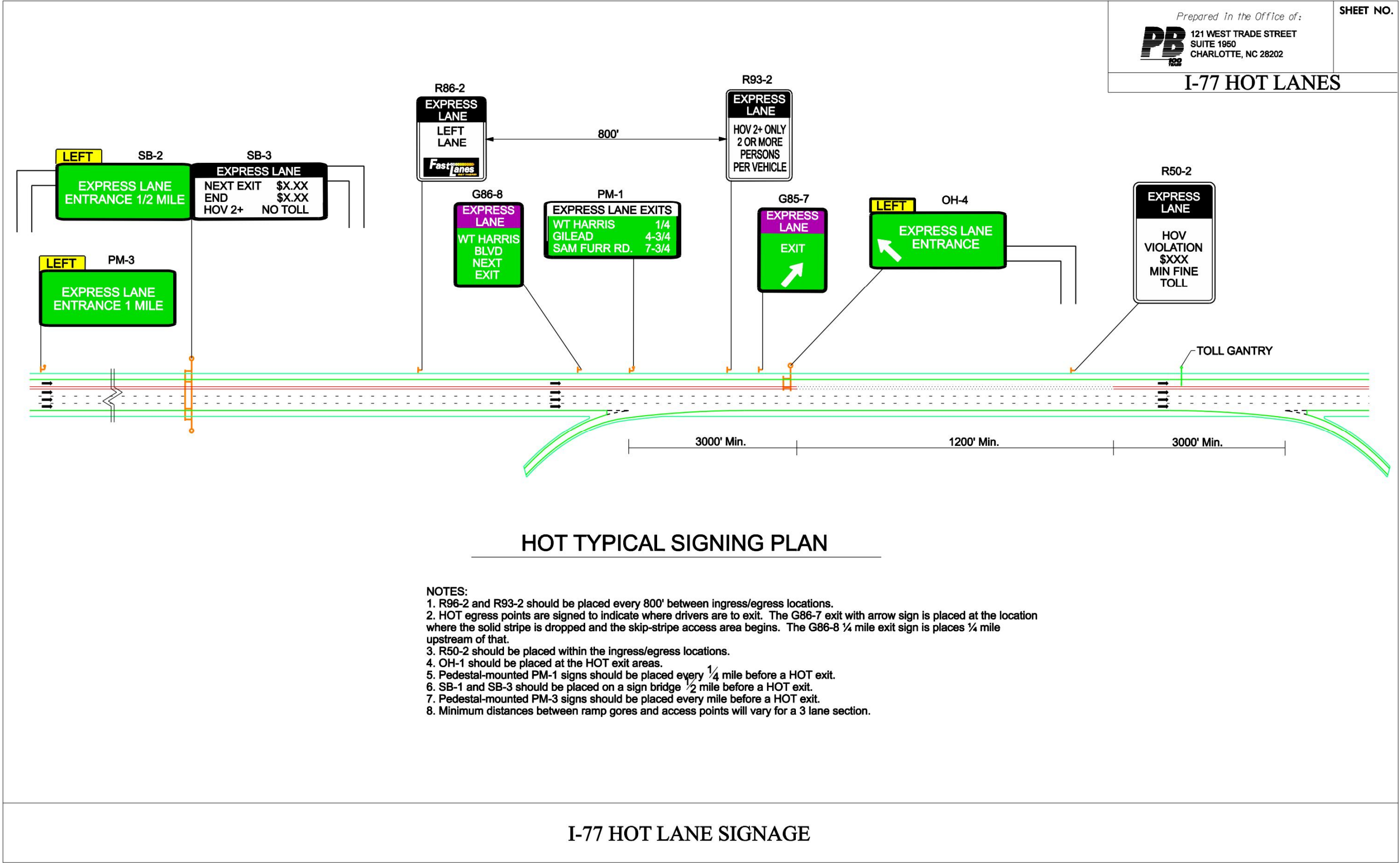


4.6 Illumination

Based on NCSHP input, additional median illumination may be needed at the HOT lane intermediate access locations in the vicinity of the toll gantries where a majority of enforcement monitoring would occur. Officers will need to be able to monitor occupancies of free vehicles in limited light conditions, and illumination at these locations could improve safety and visibility of enforcement personnel.

Additional illumination may also be needed at the lane drop on the northern end of the HOT lane, where merging will need to occur until such time that the lane is extended further north.

Figure 4-4: Typical HOT Lane Signing



5.0 OPERATIONS POLICIES

This chapter presents the operating policies to be applied for the HOT lanes facility. These policies are a continuation of those implemented in 2004 when the I-77 HOV lanes were opened.

5.1 User Requirements

The anticipated user requirements for HOT lanes operation are not intended to affect current HOV lane users. I-77 HOT lanes would continue to be open and free to vanpools and carpool vehicles carrying two or more occupants. The following sections summarize changes in facility use for various groups if HOV-to-HOT conversion occurs.

- **Motorcycles.** While federal law requires HOV lanes to be open to motorcycles regardless of the number of riders, there is no rationale not to allow motorcycles to use the HOT lane so long as they carry a transponder and pay the requisite fee. They would lose free status to ride in the lane once it is converted.
- **Emergency Vehicles.** The term “emergency vehicle” means any law enforcement, fire, police, or other government vehicle, and any public or privately owned ambulance or emergency service vehicle, when responding to an emergency. Emergency vehicles would be exempt in all cases from paying a toll; however, such vehicles need to be easily distinguished and be responding to an emergency to be eligible for free use.
- **Buses.** Any public or private transport vehicle designed to transport 15 or more passengers, regardless of the actual number of occupants, would be free to use the HOT lane regardless of whether they are carrying the requisite number of passengers or not (typically in a deadhead mode).
- **Trucks.** Any motor vehicle with three or more axles would be precluded from using the HOT lanes, continuing the current prohibition for use of the HOV lanes. Commercial vehicles with two axles, such as delivery trucks, could use the HOT lane as long as they carry a transponder and pay the requisite fee.

5.2 Hours of Operation

The existing I-77 HOV lanes operate 24 hours a day, seven days a week. The rationale for this decision is based on the design of the lane which departs from the freeway main lanes onto a separate roadway alignment through the I-85 interchange. Opening up this lane and roadway for certain time periods could cause potential confusion for motorists and could represent a safety hazard, particularly at night.

For this reason, the existing operating hours for the I-77 HOV lanes will not change under a HOT lanes conversion. The extended HOT facility would operate 24 hours a day, seven days a week. The hours of operation may be relaxed to a low toll rate during off-peak periods, and it may not be monitored or enforced during these periods. The hours of operation for user-only restrictions may be waived at any time for a portion or the entire project if, in the opinion of MRTMC staff, the HOT lane should be opened toll-free to all traffic to by-pass general purpose lane or roadway closures due to major incidents or road construction/maintenance activities. Hours of operation would be posted at entrances to the HOT lanes.

5.3 Access Policy

The current I-77 HOV facility access policy will remain in effect for the conversion of the existing HOV lanes to HOT lanes and facility extension to the north. Access to the HOT lanes would be permitted at designated locations. Access is restricted in order to properly toll specific segments of the project. Access is also restricted where there are operational or safety issues associated with merging traffic. Access restriction would typically be represented by a two wide solid stripes defining a non-traversable buffer. Areas permitting ingress and/or egress to the HOT facility would be designated by appropriate signing and a wide single white skip line located between the HOT and leftmost general purpose lane. Signing would appear at periodic intervals indicating that the buffer cannot be crossed.

Direct access ramps may be included in the HOT conversion phase or in a subsequent project development phase. Direct access ramps could provide high-speed access from another route (i.e., I-85 or I-485) or to connect to adjacent streets and transit facilities. In Task Order No. 1, direct connections to the I-77 HOV lanes were analyzed at the following overpasses:

- Bailey Road Extension
- Stumptown Road
- Mt. Holly-Huntersville Road
- Lakeview Road

Using the Metrolina travel demand model, entry and exit volumes for the PM peak hour were forecast for both 2013 and 2030 at each location. Direct connections to the I-77 HOV facility from overpasses at Bailey Road Extension and Mt. Holly-Huntersville Road would serve the most vehicles. Unless otherwise restricted, direct access ramps would be designed and operated to serve all types of HOT lane traffic.

6.0 MAINTENANCE

6.1 Maintenance Requirements

Maintenance is a complex assessment of present-day impacts and future-day risk management. To assess the impacts, maintenance agents will coordinate with operations agents to identify how operational needs affect the timing and frequency of maintenance activities. If the maintenance program is fully subservient to the operational program, then this increases the risk calculation to provider; in other words, the maintenance operator must adjust the risk assessment such that necessary preventative or recovery maintenance may not occur at an ideal time, negatively affecting performance target achievement. As such, the management of HOT lanes maintenance cannot be separated from the systems' operations or design, and as such an overarching maintenance program management is essential for ensuring active communications and rapid response. For example, the tolling and enforcement system must have a functional reliability of greater than 99.9 percent or neither the ability to price and enforce the prevailing toll can be accomplished. This functional requirement may be greater than what is typically assigned to traffic management applications, and this requirement will drive who does what type of maintenance function, and the performance they have to maintain.

There are four primary components to a HOT lane maintenance program: staffing (including training), equipment, operations, and administration (including budget, contracts, and purchasing).

Staffing activities include:

- Establishing staffing qualifications, including minimal standards for full-time and contract labor.
- Estimating staffing full-time equivalents (FTE's), including workloads and position descriptions
- Providing a staff retention program
- Providing a library and continuing-education environment for retraining
- Establishing a pre-qualification for contractors, with appropriate refreshing given changes in procedures and deployed equipment
- Ensuring bi-directional training for vendors and contractors

The equipment component comprises:

- Identify, track, and evaluate various equipment measures of performance including mean time between failures, mean time to repair, average cost to repair, design life, and salvage value.
- Maintain an inventory of field equipment, including all devices and their locations, with appropriate updates to training as device specifications change over time
- Maintain an inventory of pavement as-built and other roadway-based components
- Develop a preventative maintenance schedule for all devices and pavement, with estimated labor hours to affect the schedule
- Develop a replacement schedule for all devices and roadway pavement

The operations component involves the following activities:

- Interacting and cooperating with operations activities to ensure that ITS, toll systems, and other components consider maintainability issues
- Participation in construction inspection and acceptance testing
- Provide for replication services, including hot-swapping capabilities on core infrastructure

The administrative component includes:

- Establishing overall programmatic budget, including estimating staffing requirements by system, management requirements, and inventory/system replacement schedules
- Developing labor estimates to inform internal and contractual budgets, including total labor hours to perform work schedules, number of FTE's per crew, burn times (delay, travel time, etc.), and maintenance staging
- Planning and managing risk, including all aspects of enterprise management such as risk factors, cost estimation, allowances for spares/redundancy, and mitigation solutions
- Assisting in replacement schedules, number of spares, and staging considerations
- Contingency planning for emergency and atypical situations
- Managing contracts, bid process, and other associated programs

For the I-77 HOT lanes, maintenance goals will be articulated in terms of operational levels. Standard performance metrics include: mean time between failures (a dual function of design life and preventative maintenance, forestalling failure); mean time to repair (expressed as number of hours); average cost to repair; design life; and salvage value. The key metrics for HOT lanes are downtime in operational hours (critical timing being peak periods, with relaxed timing in evenings and other times of day when the corridor is operating at acceptable levels of service), failure rates for critical components to operations and tolling, and timeliness of response for maintenance. As detailed metrics are defined, the preferred maintenance operator must be able to meet all three HOT lane elements in addition to the minimum standard performance metrics. Meeting these requirements could be costly – for example, 24/7 operations with a low response time (as was required on I-95 Express Lanes by the Florida TMC private contract) means that one FTE position across that 24/7 spectrum is actually held by five employees on a part-time basis. Thus, NCDOT will want to establish critical times of response (peak periods and directions), standard times of response (daytime off-peak periods and directions), and relaxed times of response (evenings / times of low corridor volumes). Different responses can be adjusted accordingly. Public sector options may not be well suited to handling these different staffing requirements for response; whereas, private sector arrangements may be articulated contractually though may be more costly for a single HOT lane operation.

The maintenance program will include specialized training such as procedures for individual devices, operations and calibration of test equipment, and technologies, equipment, and practices for repairing essential components of the system. This training will require refresher courses in addition to new staff training, as certain components become operationally obsolete and new procedures are established. As a result, the toll system integrator will inevitably be involved in training staff and have a performance mandate to ensure that the system is maintainable after installation. Finally, whereas warranties are helpful for capital equipment, the labor cost for replacement of faulty equipment is not typically covered to repair or install new hardware. Under a private sector contracting arrangement if applied, the labor costs associated with repair and installation can be accounted for prior to implementation.

6.2 Lane Pavement, Structures, Fixed Signs and Pavement Markings

Of course not all maintenance requirements are critical to HOT lane operations, and most typical and routine functions merely need to be verified. Some requirements may be different because the reliability to be ensured means that debris must be removed where no inside shoulder is provided, and drainage may require greater scrutiny where design exceptions do not leave the proper offset for ponding around inlets, or the application of inlets such as slotted drains that are more prone to needing maintenance. Listed below is an example set of tables that comprise basis maintenance needs for HOT lanes that should be reviewed with respect to regular freeway maintenance functions to determine if the frequency suggested is greater or about the same as is currently applied.

FLEXIBLE PAVEMENT

Maintenance Code	Description of Labor, Equipment, Materials, Planning, Supervision.	Estimated Frequency: Daily, Weekly, Monthly, Annually	Required Respond Time for As-Needed Maintenance
ROADBED ACTIVITIES			
A10001	Inspection - Flex Lane	weekly	
A10002	Complaint Investigation/Flex Lane	as-needed	4 hours
A10010	Seal - Flex Lane	annually	
A10020	Crack Seal - Flex Lane	annually	
A10030	Patch Pot Holes - Flex Lane	as-needed	24 hours
A10040	Dig Out - Flex Lane	annually	
A10050	Profile Grinding -Flex Lane	annually	
A10060	Overlay/Leveling - Flex Lane	annually	
RAMPS ACTIVITIES			
A11001	Inspection - Ramps	weekly	
A11002	Complaint Investigation - Ramps	as-needed	4 hours
A11010	Seal - Ramps	annually	
A11020	Crack Seal -Ramps	annually	
A11030	Patch Pot Holes - Ramps	as-needed	24 hours
A11040	Dig Out - Ramps	annually	
A11050	Profile Grinding - Ramps	annually	
A11060	Overlay/Leveling - Ramps		
SHOULDER ACTIVITIES			
A12001	Inspection - Shoulders	weekly	
A12002	Complaint Investigation - Shoulders	as-needed	4 hours
A12010	Seal - Shoulders	annually	
A12020	Crack Seal - Shoulders	annually	
A12030	Patch Pot Holes - Shoulders	as-needed	24 hours
A12040	Dig Out - Shoulders	annually	
A12050	Profile Grinding - Shoulders	annually	
A12060	Overlay/Leveling - Shoulders	annually	

DRAINAGE INLETS, DRAINS

Maintenance Family	Description of Labor, Equipment, Materials, Planning, Supervision.	Estimated Frequency: Daily, Weekly, Monthly, Annually	Required Respond Time for As-Needed Maintenance
DRAINAGE INLETS			
C64001	INSPECTION	weekly	check and clean after a storm within 24 hours
C64002	COMPLAINT INVESTIGATION	as-needed	4 hours
C64010	REPAIR/REPLACE	as-needed	24 hours
C64050	CLEAN	annually	check and clean after a storm within 24 hours
HORIZONTAL DRAINS			
C70001	INSPECTION	weekly	check and clean after a storm within 24 hours
C70002	COMPLAINT INVESTIGATION	as-needed	4 hours
C70010	REPAIR/REPLACE	as-needed	24 hours
C70050	CLEAN	as-needed after a storm	check and clean after a storm within 24 hours
UNDER DRAINS			
C71001	INSPECTION	weekly	check and clean after a storm within 24 hours
C71002	COMPLAINT INVESTIGATION	as-needed	4 hours
C71010	REPAIR/REPLACE OPENING	as-needed	24 hours
C71050	CLEAN	as-needed after a storm	check and clean after a storm within 24 hours

DELINEATORS, GUARDRAILS, BARRIERS, ATTENUATORS, MISC, RAMPS

Maintenance Family	Description of Labor, Equipment, Materials, Planning, Supervision.	Estimated Frequencies: Daily, Weekly, Monthly, Annually	Required Respond Time for As-Needed Maintenance
GUARDRAILS			
M60001	INSPECTION	as-needed	monthly
M60002	COMPLAINT INVESTIGATION	as-needed	4 hours
M60010	REPAIR/REPLACE (RAIL ONLY)	as-needed/special needs	24 hours
M61010	REPR/REPLC (ENDTRTMNT)	as-needed	24 hours
BARRIER			
M70001	INSPECTION	as-needed	monthly
M70002	COMPLAINT INVESTIGATION	as-needed	4 hours
M70010	REPAIR/REPLACE	as-needed/special needs	24 hours
ATTENUATOR			
M80001	INSPECTION	as-needed	monthly
M80002	COMPLAINT INVESTIGATION	as-needed	4 hours
M80010	REPAIR/REPLACE	as-needed	24 hours
MISCELLANEOUS			
M90000	EMERGENCY TRAFFIC CONTROL	as-needed	1 hour

STORM PATROL/DAMAGE

Maintenance Code	Description of Labor, Equipment, Materials, Planning, Supervision.	Estimated Frequency: Daily, Weekly, Monthly, Annually	Required Respond Time for As-Needed Maintenance
STORM PATROL/DAMAGE			
S20000	STORM PATROL	as-needed	2 hours
S20100	FLOOD CONTROL	as-needed	2 hours
S30000	EMERGENCY DAMAGE REPAIR	as-needed	24 hours
S30001	INSPECTION	as-needed	check after a storm within 24 hours
S30002	COMPLAINT INVESTIGATION	as-needed	4 hours
S30100	CLEARING ROAD OF SAND/DEBRIS	as-needed	24 hours

STRIPING, MARKINGS, SIGNS, STRUCTURES

Maintenance Code	Description of Labor, Equipment, Materials, Planning, Supervision.	Estimated Frequency: Daily, Weekly, Monthly, Annually	Required Respond Time for As-Needed Maintenance
STRIPING			
M10001	INSPECTION	as-needed	monthly
M10002	COMPLAINT INVESTIGATION	as-needed	4 hours
M10003	NIGHT INSPECTION	annually	
M10010	REPAIR/REPLACE	as-needed/special needs	1 week
M10070	PADDLE MAINT.	as-needed	1 week
MARKINGS			
M20001	INSPECTION	as-needed	monthly
M20002	COMPLAINT INVESTIGATION	as-needed	4 hours
M20003	NIGHT INSPECTION	annually	
M20010	REPAIR/REPLACE	as-needed/special needs	1 week
M20020	PLACE - DAY LABOR	special needs	1 week
PAVEMENT MARKERS			
M30001	INSPECTION	as-needed	monthly
M30002	COMPLAINT INVESTIGATION	as-needed	4 hours
M30003	NIGHT INSPECTION	annually	
M30010	REPAIR/REPLACE	special needs	1 week
SIGNS			
M40001	INSPECTION	as-needed	monthly
M40002	COMPLAINT INVESTIGATION	as-needed	4 hours
M40003	NIGHT INSPECTION	annually	
M40010	REPAIR/REPLACE	as-needed/special needs	48 hours
SIGN STRUCTURES			
M41001	INSPECTION	as-needed	monthly
M41002	COMPLAINT INVESTIGATION	as-needed	4 hours
M41010	REPAIR/REPLACE	as-needed/special needs	1 week
M41060	PAINT	as-needed	annually

6.3 Maintenance Responsibilities

NCDOT's Division 10 would be responsible for maintaining the HOT and/or general purpose lanes similar to current operations for the existing I-77 HOT lanes. The agency contracts with a private company to provide maintenance services on 131 directional miles of interstate roadway in Mecklenburg, Gaston and Cleveland counties. The contract covers highway surface upkeep and a related number of other functions.

For HOT lane tolling and enforcement systems, a private contractor would be anticipated to perform maintenance at least for the first two to three years under a systems integration performance extended agreement that would be part of the installation contract. Thereafter, this role could be contracted out or performed by NCDOT/NCTA or a third party provider. A decision regarding longer term maintenance would be predicated on when other toll facilities in the region are operational because it is likely that economies of scale would result using the same maintenance providers for all electronic tolling and enforcement systems.

7.0 TOLL COLLECTION AND SYSTEM CONCEPT

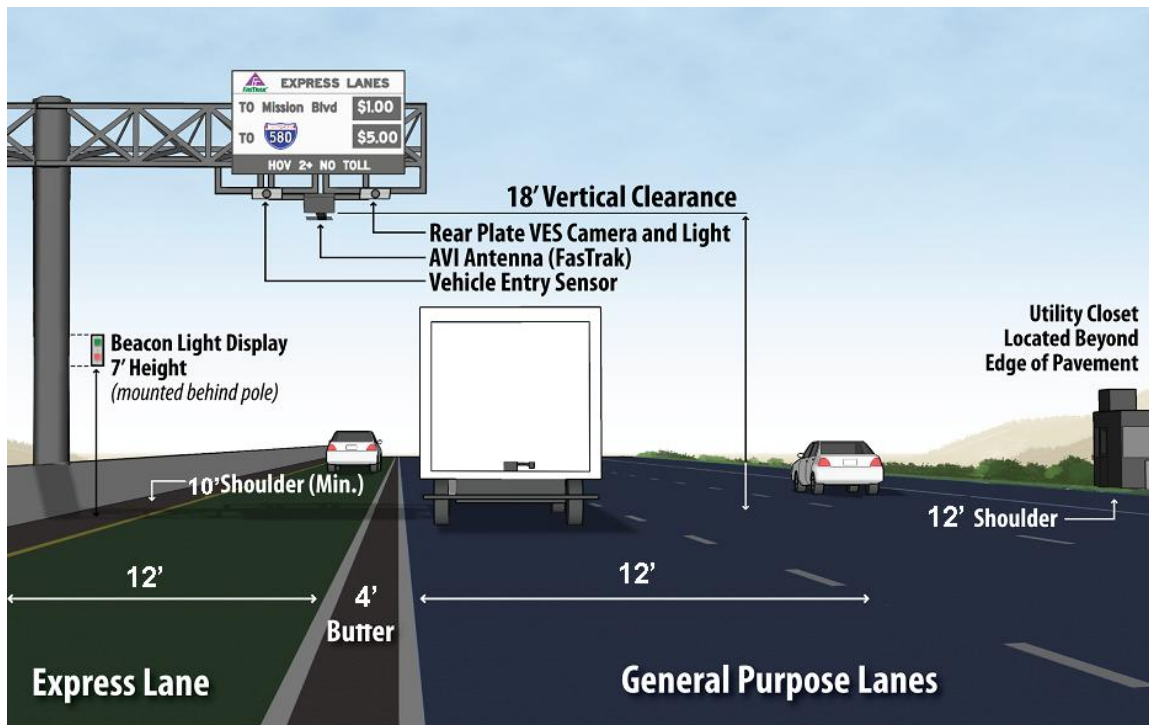
7.1 System Overview

The toll collection system for the I-77 HOT lanes must be compatible with other toll facilities in the region and state, while also being responsive to the unique user requirements. These requirements relate to the design with rather unlimited opportunity for violators to enter and exit the lane at will, and a potential need to adjust tolls dynamically by time of day for each segment of the roadway. Furthermore, the system may also need to account for stratifying tolls sometime in the future to allow carpools with two or more occupants to use the lanes for a discounted toll if their numbers eventually overwhelm HOT lane capacity.

It should be noted that whereas the nexus of the toll collection system in the Operations Plan is applying appropriate prices for use of the HOT lane, the footprint of the system will have to extend into the general purpose lanes for support structures and traffic monitoring, among other needs. This requirement has a cascading effect upon maintenance and the ability to access signing and equipment without lane closures, to the degree practical. For example, this system will include automatic vehicle identification (AVI) readers that extend over not only the HOT lane, but also the leftmost general purpose lane. This is done in order to separate vehicle transponders to be tolled.

Upstream of the next entrance to the HOT lane, a gantry (either single column cantilever or facility-span) will extend across the HOT lane and left-most general purpose lane. Co-location of AVI antennas on the same gantry substantially minimizes the chance of error-based reads (such as a general purpose lane user being misread as a HOT lanes customer). AVI antenna are installed over the HOT lane and left-most general purpose lane. Additionally, a variable message sign (VMS), positioned over the general purpose lane, will advise the traveler of the toll rate in effect and total cost to select downstream destinations. At each toll zone, the gantry includes lighting and cameras for a rear-facing Violation Enforcement Systems (VES), as shown in **Figure 7-1**. The AVI will signal to the back-office the initiation of a potential trip record for the transponder-equipped vehicle, with a tag associated with the toll rate active at the time of the initiation. This is considered a first-read event, with all subsequent events associated with this trip record. If the driver chooses to enter the HOT lane, then the last-read event (upon exit) is used to create a trip pair with calculation of total toll cost based upon the prevailing toll rate at the time of the first-read event. Each read event records the transponder identification number, license plate number (in select toll zones with Violation Enforcement Systems), date, time, and location identification number. If the driver elects to remain in the general purpose lane, no toll record will be recorded for the trip. The central processing system will record the next event in the general purpose lane and determine that the vehicle did not use the lane. Each subsequent pass reopens the potential trip record creating a trip assembly for the purposes of calculating the toll.

Figure 7-1: Sample Toll Zone



Travel time data for customers and non-customers will be maintained in order to establish travel times and average speeds between read events. In effect, every transponder-equipped vehicle that successfully completes a read-event pairing serves as a probe vehicle for travel times. This data may augment additional traffic detection and sensing equipment, providing feedback to the dynamic price setting subsystem.

In addition to toll evasion enforcement, the VES also augments the toll collection system to ensure completeness of data. If a transponder is inaccurately read, or if there is missing data after a first-read event, the VES will be used to substitute the data. Optical character resolution (OCR) is performed on license plate capture images for comparison and verification of account status for the last recorded position and first unrecorded position, to ensure a completed trip record (and toll charge) is performed. Without conducting the VES comparison, inaccurate entry and exit reads may occur, with inaccurate toll charges assessed. Conversely, if no first-read event is recorded on the general purpose lanes – and the system only shows the account having initiated within the HOT lane – then the entry point must either be estimated based upon VES data (which may be subject to error) or only those points with successful data transactions recorded (which would yield revenue leakage).

7.2 Business Rules for Calculation of Tolls

In general, NCDOT/NCTA policies will control the business rules related to HOT lane operation and enforcement and account management. The following tables cover a broad array of topics related to all of the business rules and functions requiring resolution.

BAY AREA EXPRESS LANES BUSINESS RULE MATRIX

	Current ETC	Proposed
	HOT Lane Practice	I-77 Practice
CUSTOMER SERVICE		
Contact Methods		
Walk-in	one location	one location
Website	each area has their own	yes
Phone (direct, IVR, ACD)	in use	default to current NCTA practice
Voice Broadcast	not typically	not required
Fax (incoming)	yes	default to current NCTA practice
Direct Mail/Letters	yes	default to current NCTA practice
E-mail	yes	default to current NCTA practice
Mobile Unit	no	no
Retail	yes	default to current NCTA practice
Languages Supported?	English, Spanish	default to current NCTA practice
ADA treatments?	customer service center am to 5 pm , Sat 9 am to 1 pm	customer service center
Business hours for each method		default to current NCTA practice
FasTrak Account Types		
Standard, Pre-paid	yes	Default to current NCTA practice
Post-Pay	yes	
Commercial	yes	
Non-Revenue	yes	
Employee	no	use mylar bag if HOV
Service	no	
Occupancy-Based	no	
LP Only (no transponder)	no	
Transponder Only (no LP)	no	Default to current NCTA practice
Anonymous	yes	
Gift Certificates	no	
Discount Programs	no	
Promotions	no	
Frequent User Program	no	
In-Kind Services	no	
Special Rules for:		
Motorcycle	free use allowed M - F, 5 - 9 am, 4 - 6 pm; use mylar bag	allowed to go free - how?
Hybrid	some allow free use	no
Carpool	free use allowed M - F, 5 - 9 am, 4 - 6 pm; use mylar bag	use mylar bag if HOV
Vanpool	no	no
Transit	no	allowed to go free - how?
Law Enforcement	yes	allowed to go free - how?
Public Safety	yes	allowed to go free - how?
Tags from Other State Toll Facilities	yes	yes

BAY AREA EXPRESS LANES BUSINESS RULE MATRIX

	Current ETC HOT Lane Practice	Proposed I-77 Practice
Account Management		
Allowed Enrollees / Restrictions	none noted	Default to current NCTA practice
Minimum Age of Account Holder	none noted	
Allowed Account Holder (OK if account holder is not registered vehicle owner? OK if account holder is not the same name on credit/debit card? etc.)	no restrictions noted	
Application / Terms and Conditions	as exists	
Account Access	as exists	
Required Account Information, including alternates	as exists	
Account Opening, Updating, Deactivation, Closing	as exists	
Transponder Add / Delete	as exists	
Account Status (open, closed, pending closed, low balance, etc.)	as exists	
Information Requests	as exists	
Account Statement Processing	online or quarterly email = free; paper statement incur cost	
Inactive Accounts	no restrictions noted	
Accounts in Bad Standing, Write-offs	as exists	
Service Fee for High Use on other Facilities	yes	
Tag Movement between Vehicles	yes	
Tag Limit per Account	none	
Privacy Requirements	as exists	
Payment Methods		
Cash	yes	Default to current NCTA practice
Check	yes	
Credit Card	yes	
Debit/ATM Card	prefer not to use	
Electronic Funds Transfer	no	
PIN-Based Card	no	
Money Order	yes	
Traveler's Check	no	
ACH	no	
Non-US Methods	no	
Counterfeit Payments	as exists	
Unidentified Payments	as exists	
Primary and Secondary Methods	no	
Discounts	loaded at lane so applies to all transponders, including away agencies	
Reminders/Alerts	yes	

BAY AREA EXPRESS LANES BUSINESS RULE MATRIX

	Current ETC	Proposed
	HOT Lane Practice	I-77 Practice
Payment Processing/Fees		
Different Rules for Credit/Debit Based Accounts vs. Cash	yes	Default to current NCTA practice
Pre-paid Toll Balance	credit/debit card = \$25 cash/check/money order = \$50	
Account Payments	cash, check, or credit/debit card thru walk-in, web, mail, phone	
Toll Payments	only thru ETC	
Replenishments	auto replenishment of \$25 when balance drops below \$15 for credit/debit card or \$40 for cash/check/money order when balance drops below \$30; also calculated based on usage	
Adjustments	as exists	
Refunds (full and partial, no refunds of \$1.00 or less?)	no restrictions	
Transfers	as exists	
Underpayments	as exists	
Overpayments	as exists	
Deposits	credit/debit card accts = deposit waived for first 3 tags; after 3 tags, deposit of \$20 for each tag; cash/check/money order accts = \$20 deposit per tag; refunded when acct closed and tags returned in good condition	
Pay by Phone	no	
Negative Balances	violations; acct closed after 90 days; all deposits forfeited	
Returned Payments	returned check fee = \$25	
Disputes	settled if valid; otherwise pursued	
Card Expirations	reminders sent; acct alerts	
Paper Statement Fee	\$1	
Pay by Plate Fee	no	
Missing LP on Acct Fee (v-toll)	?	
Monthly Minimum Usage Fee	no	
Collections Fee	no	
Interoperability Fee (future)	no	

BAY AREA EXPRESS LANES BUSINESS RULE MATRIX

	Current ETC HOT Lane Practice	Proposed I-77 Practice
Non-FasTrak Accounts (i.e. violators)		
Manual Image Review	yes	Default to current BATA practice
DMV Look-up	yes	
Violation Multi-level Noticing	1st notice = toll + \$25; 2nd notice = toll + \$70; if paid within 15 days, fine reduced to \$25	
Escalation	yes	
Conversion	yes	
Waivers	yes	
Disputes	settled if valid; otherwise pursued	
Affidavits	yes	
Admin Hearings	avoided	
Payments	cash, check, or credit/debit card thru walk-in, web, mail	
Inactivity	no restrictions	
DMV Holds (applying and releasing)	yes; \$3 charge for hold	
Pre-disposed Sources of Leakage:		
Out of State/Country Plates	no pursuit	
Dirty Plates	no pursuit	
Obscured/Obstructed/Altered Letters or Numbers	no pursuit	
Faded/Damaged/Missing Plates	no pursuit	
Dealer Plates	no pursuit	
Plates with Frames where numbers or letters are obstructed	no pursuit	
Plates containing a non alpha-numeric character (star, heart, etc.), vanity plates, vertically stacked letters	no pursuit	
Collections	?	
Egregious Listing (for CHP)	no	
Transponder Management		
Transponder Types	internal, external	Default to current BATA practice
Lost, Stolen, Damaged, Unreturned Transponders	lost, stolen, damaged; deposit is retained; charge for replacement	
Malfunctioning Transponders	replaced for free	
Returned Transponders	fee charged	
Unauthorized Use	varies, protocols reqd	
Inventory Control	yes	
Transponder Validation	no	
Mylar Bags	yes	
		yes

BAY AREA EXPRESS LANES BUSINESS RULE MATRIX

	Current ETC	Proposed
	HOT Lane Practice	I-77 Practice
Customer Satisfaction		
Satisfaction Guarantee	no	Default to current NCTA practice
Complaint/Dispute Tracking	?	
Escalation Process	yes	
Resolution Tracking	?	
Mystery Shopper Program	?	
Survey Tools	?	
LANE LEVEL		
Device Sequencing	well established	pending
Transaction Processing	well established	pending
Trip Creation (full trips, half trips, partial trips)	well established	pending
Image Production (for review)	well established	pending
In-Lane Display	displays acct status to each vehicle	no specific comm to vehicle; generic display to all
Tag Beeps	beeps twice	no
Toll Structure Modification/Release/Update	infrequent	could be every 5 minutes
Fixed, Dynamic, or Hybrid Pricing	fixed toll	dynamic pricing
ROADWAY OPERATIONS		
Traffic Diversions/Detours	well established	well established
Lane Closures (full, partial, limited)	well established	well established
Incident Management, Notification, and Reporting	well established	well established
Sign Messaging / Overrides	not relevant	not relevant
Amber Alerts	not part of toll system	no
Allowed CCTV and VES Video Viewing	well established	well established
Courtesy patrol hours of operation, allowed level of support	varies	covers peak periods
NCSHP hours of operation	dedicated, contracted	dedicated, contracted
Vehicle Access Limitations (no trucks, wide loads, or overweight vehicles)	none	none
Alarms, Alerts, Failures	well established	
MISCELLANEOUS		
Data Storage, Archiving, and Availability Requirements	?	
Search Warrants	not an issue	
Subpoenas	not an issue	
HOV or Toll Evasion Laws	Toll Evasion Laws	HOV Law, fine = \$341 and CHP keeps the fine

7.3 Toll Collection Signage

Signs displaying the prevailing toll rate will be located at least one-quarter mile in advance of each ingress location, and not further than a half-mile in advance.

7.4 Communication Network and Electrical Requirements

A separate fiber optic conduit will be installed along the corridor to serve as the communication link between tolling and enforcement equipment and back office monitoring and processing. While this link may be able to use NCDOT traffic monitoring infrastructure in the field (subject to a value engineering assessment), cost estimates at this feasibility stage assume a separate dedicated conduit and independent communication system. This assumption is also based on the expectation that a separate maintenance provider or system integrator will be responsible for a high level of functional reliability for the installed communication system.

Existing nodes on the NCDOT fiber optic cable backbone provide communication services to some CCTV cameras installed for surveillance and provide an opportunity for transmitting video and data to the MRTMC and NCDOT/NCTA Central Processing (via an interconnection to the public network). Use of the existing ITS infrastructure fiber backbone may allow allocation of at least one dark fiber that may be used in conjunction with a local carrier's network for linking a transponder read zone with NCDOT/NCTA Central Processing. Alternatively, the use of current ITS equipment (e.g. VMS, CCTV), mounted to a pole or cantilever structure, represents an opportunity to mount a transceiver, radio or antenna to support wireless communication.

The utility company having a franchise agreement to provide electrical service in the vicinity of the I-77 HOT lanes facility will need to be determined and contacted during the design phase to discuss the need for service at the toll zone, read zones, pricing sign and traffic controller locations. Coordination with utility companies will be necessary to determine the availability of existing transformers that can service the HOT lane field equipment at a lower cost than installing a new transformer and the associated overhead or underground electrical cabling by the utility company. Routing electrical cable from an existing electrical panel installed in conjunction with a VMS or CCTV surveillance camera site located within the I-77 project limits to one or multiple HOT lane equipment sites requiring power should be investigated. If NCDOT allows a connection to this panel, the cost associated with using this source should be compared to the cost of obtaining electrical service from the utility company's new or existing source through which electrical service is delivered to each HOT equipment site that requires power. If electrical service is obtained from the utility company, a transformer that steps the available voltage down to 120/240 VAC is required to power the HOT equipment at each site. It is envisioned that unit ductwork will be installed by the contractor to route cable from either an existing electrical panel or the utility company's transformer to a particular site. The utility company providing the service or a licensed electrical contractor would make approved connections to the designated transformer(s).

7.5 Toll Collection System Configuration

HOT lane facilities commonly have multiple toll zones where transactions are recorded and sent to a central processing server where transaction records containing the same transponder ID are combined into a trip, subject to a maximum time difference on consecutive transactions. The trip is then assigned a price that the system determines the user viewed when entering the facility, usually by applying rules that result in the lesser of two possible tolls displayed closest in time to the system calculated entry time. Transaction records are built within the field tolling system and sent to Central Processing at the NCDOT/NCTA Data Center in near real-time. Since multiple toll zones are planned, a trip building process is an important component in the field that can reduce cost with one transaction fee incurred per user trip.

7.6 Vehicle Detection and Toll Collection Subsystem

Accurate vehicle detection is required to generate raw traffic data for input to a pricing algorithm that continuously calculates the price for single-occupant vehicles to use the facility such that free-flow conditions are maintained. New vehicle detectors will need to be installed along the I-77 HOT lanes in each direction at about half-mile spacing. Agencies have implemented a HOT lane system that collects traffic data in the general purpose lanes for the purpose of pricing the HOT lanes based on time saving relative to the general purpose lanes or as a means of validating HOT lane traffic data by correlating traffic trends. The later process also adds redundancy to the system so operations can continue if controller communications for the HOT lane fail. Given a HOT lane pricing scheme objective of maintaining free-flow conditions, three alternatives for supplementing and adding redundancy to traffic data collected in the HOT lanes are:

1. Install non-intrusive vehicle detectors (e.g., RTMS) to collect traffic data in all travel lanes at locations that are coincident with each HOT lane vehicle detector,
2. Install a read zone in each direction and use vehicles with valid transponders as probes to calculate travel time and speed in the HOT lane between the toll and read zones.
3. Rely on existing vehicle detectors installed in the general purpose lanes to extrapolate travel conditions in the HOT lane.

The advantages and disadvantages of these three alternatives are presented in **Table 7-1**.

Table 7-1: Advantages and Disadvantages of Vehicle Detection and Toll Collection

Alternative	Advantages	Disadvantages
1	Traffic data can be simultaneously collected in each general purpose lane and the HOT lane by a single sensor, providing a means to validate and supplement the vehicle detector data collected in the HOT lanes, particularly important when vehicle detector station (VDS) data is not available for input to the pricing process.	Studies have shown some degradation in performance of radar based sensor technology in slow moving congested flows that may result in over counting vehicles (note: in-pavement vehicle detectors tend to undercount in bumper-to- bumper traffic)
	A non-intrusive, roadside-mounted vehicle detector eliminates any disruption to traffic, which is inherent to replacing an in-pavement sensor and associated wiring.	Radar based sensors may need to be periodically recalibrated to correct drift in accuracy.
	Collection of general purpose lane traffic data allows the validation of traffic speed and density trends calculated in the HOT lane by comparing to calculated traffic data trends in the general purpose lanes, which are a precursor.	Poles used to mount a radar based sensor need to be protected by guardrail or barrier, assuming installation off the right shoulder in each direction of travel.
		Power and communication is required for each radar based sensor installed just beyond the outside shoulder in each direction of travel.

Table 7-1: Advantages and Disadvantages of Vehicle Detection and Toll Collection (cont.)

2	In addition to providing a reliable means of calculating travel time and speed when combined with toll zone data that can be input to the pricing process, a read zone is expected to eliminate cross lane reads and support an advisory sign, where applicable.	Maintenance of the read zone equipment installed on the cantilever structure requires traffic control devices and likely the closing the HOT lane.
	Calculated traffic data is immune to the speed and density of the traffic stream, unlike the majority of commercial vehicle detectors.	Requires boring/jacking conduit under the GP lanes and Express Connector to route power and communication from a roadside cabinet to a cantilever or "T" structure.
	Because of high accuracy, lower volumes of transponder-equipped vehicles will not degrade performance, assuming the presence of at least one such vehicle during the pricing change interval.	Structures and roadside cabinets add clutter to the facility's appearance. (Note: This can be mitigated by a "T" structure which reduces by half the number of structures and roadside cabinets; maximizing utility of the structure by mounting an advisory sign reduces clutter for all structure types)
3	Avoids incurring any additional cost to install detectors for validating HOT traffic speed and density trends by comparing to the same trends in the general purpose lanes based solely on VDS installed within the project.	Existing vehicle detectors (loops) are only located at the limited locations
	By maintaining an historical moving average of scale factors derived by dividing HOT traffic statistics by general purpose lane traffic statistics during weekday/weekend peak, shoulder and off-peak periods, general purpose lane traffic data can be adjusted for input to the pricing process when HOT traffic data is unavailable.	Maintenance of the existing general purpose lane vehicle detectors requires traffic control devices to temporarily close a lane.
	Existing health of the vehicle detectors installed within the project is not 100 percent, so reliance on these is problematic.	Requires center to inside general purpose lane VDS data within the project to be parsed by NCDOT/NTCA prior to input to a process within the pricing module.
		Calculation of traffic data trends for both general purpose lanes and HOT lanes by a process within the pricing module over configurable time periods adds complexity to the software. Converting historical general purpose lane trends to HOT lane pricing module input data for discrete traffic periods when the facility VDS is not available further adds to complexity.

7.7 Vehicle Data Collection, Communication and Processing

To successfully implement dynamic pricing on the I-77 HOT lanes, new VDS must be installed at close spacing to accurately measure facility speed and density for input to a dynamic pricing algorithm that continuously calculates single-occupant vehicle pricing. The objective of the pricing is to maintain free flow conditions along the HOT lane discouraging users of single-occupant vehicles from entering the facility as speeds decrease and densities increase. A preferred approach is either to 1) collect HOT lane traffic data using vehicle detectors connected to a roadside traffic controller installed at each station, from which the raw data is transmitted via a leased line from a local carrier to the NCDOT/NCTA data center, where it is pre-processed for input to the pricing algorithm; or 2) collect HOT lane traffic data using vehicle detectors connected to a roadside traffic controller installed at each station and using point-to-point wireless communications (i.e., by means of a laser or microwave solution not requiring a FCC license) to a remote facility, where the raw data is routed to NCDOT/NCTA's data center via an existing T1 channel leased line from a local exchange carrier.

Maintenance of the tolling and enforcement systems requires specialized attention, which may be specific in nature to the technology deployed by the tolling integrator. This technology, though, may be present outside of the roadway right-of-way. For example, tolling algorithms require a significant amount of detector data across multiple lanes of traffic (HOT lanes and general purpose lanes) in order to operate effectively. Given constrained design, and an inability to provide for maintenance concurrent with active operations, a loss in operation may mean either loss in revenue or express lane availability, each with their own consequences for mobility, revenue and customer satisfaction. To avoid these consequences, maintaining these tightly integrated systems require a high level of reliability and field maintenance.

In most situations, tolling and enforcement systems may be maintained by the tolling integrator, especially to the extent that any loss in equipment or procedural availability will have an impact upon performance. As a result, the integrator has every interest to maintain adequate preventative maintenance in order to avoid demand-response maintenance. In the future, NCDOT/NCTA may elect that tolling system maintenance may be operated by a third-party provider under a separate performance contract from that of the tolling integrator. However, even with augmented funding, NCDOT maintenance forces could be limited with respect to accommodating additional maintenance needs or a higher standard of maintenance compliancy, at least for functions deemed critical to the intended HOT lanes performance objectives.

8.0 REVENUES

8.1 Collection

A NCDOT/NCTA Regional Customer Service Center (RCSC) could be used to process transaction and violation records for single-occupant vehicle users as it would be doing for other regional toll facilities. The RCSC is expected to be capable of processing the volume of transaction records generated by the I-77 HOT lanes with little impact on existing resources. Furthermore, NCDOT/NCTA would be capable of processing license plate images and associated transaction data as it would be doing for other toll facilities. The significance of this opportunity is enhanced with the existence of an interface control document (ICD). This document will provide the I-77 HOT lane system integrator with the framework of the interface to Central Processing located at the NCDOT/NCTA data center to the RCSC. Interface to the RCSC would be expected to significantly reduce back office software development, with a commensurate reduction in the time required to bring the HOT lane operation facility on-line. The RCSC is expected to provide the following services:

- Perform all required I-77 HOT lane account management functions;
- Perform customer service functions, including call center operations, storefront for walk-in customers, and Web site and IVR support services;
- Interface to the NCDOT/NCTA Central Processing so I-77 HOT lane trips are posted to NCDOT/NCTA accounts and for receipt of a transponder account status list, toll revenue reports, and customer license plate information;
- Transponder fulfillment services for new accounts and replacement of defective transponders; and
- Customer correspondence.

8.2 Auditing

Separation of central processing and RCSC/account management services provides an important means of checks and balances that assures every trip sent to the RCSC is accounted for as recognized revenue or a reason code that indicates why the trip could not be processed. The reasons behind single-occupant vehicle transactions/trips not resulting in revenue is routinely validated during audit and reconciliation. To perform this vital function, central processing needs to be staffed with people qualified in management, system administration, accounting and administrative/clerical work. If NCDOT/NCTA elects to use a service provider for Central Processing, contract requirements should require compliance with FASB and require procedures that streamline audit processes that are performed on a regular basis to assure the public interest is being served.

8.3 Revenue Allocation

Revenue would be expected to first cover the direct incurred cost for tolling and related operations and maintenance as defined. Typical toll related costs include the incremental burden associated with account management, transaction processing, Central Processing and CSC functions. Additional operations costs relate to enforcement, maintenance and supporting functions such as service patrols over and above what is currently allocated and budgeted. Beyond these agreed-upon costs, excess revenue may be applied to a wide variety of other corridor or service related functions that, by matter of policy, may be subject

to a wider number of agency input. Other HOT lane projects have applied excess revenue to cover capital construction and improvements to the HOT lane and transit capital and services in the corridor from which revenues were generated. Each project and setting is different. Policies will need to be established that clearly identify and address each category of cost and potential means of addressing these through revenue or other funding sources.

8.4 Account Management

Account management is assumed to be the responsibility of NCDOT/NCTA and will be implemented after opening of other toll facilities in the region. Various business rules addressed separately address the different topics affecting account management.

9.0 TRAFFIC MANAGEMENT

9.1 Needs and Point of Interface

The points of contact with respect to traffic management will primarily be between the MRTMC and the dedicated point of contact responsible for I-77 HOT lane operations. For I-77, this is likely to represent a part- or full-time staff position ideally located within the MRTMC whose responsibilities will be managing HOT lane operations. This role could be shared with a host of other functions including maintenance and third-party contract oversight. Traffic management will need a corresponding point of contact within the NCDOT/NCTA back office because there will need to be protocols for crediting customers whose accounts have been charged when major incidents or other events block the I-77 HOT lane. This point of interface needs to include the toll processing agent for accounts associated with this project.

9.2 MRTMC Interface

Within the MRTMC, a formal interface process needs to be established between the I-77 HOT lanes manager and other functional personnel including NCSHP, who may be contracted to provide regular enforcement and to follow established protocols for handling any incidents on the roadway.

9.3 Enforcement Needs

Enforcement of the I-77 HOT lanes is critical to the operational performance of this facility and perceived system reliability by prospective users, particularly the single-occupant vehicle users who are required to pay for time savings and travel performance relative to the general purpose lanes. HOT lane design elements can contribute to violations and add complexity to finding a solution that does not unduly affect operational performance resulting from either a lack of or too much enforcement. Signing must be clear and properly located for users to quickly assess the costs and benefits of using the HOT lanes and to avoid misunderstanding the rules governing the use of the facility.

The types of violations that could occur along I-77 HOT lanes include:

- **Occupancy.** Vehicle contains fewer occupants than what is required for HOV status. This determination would be assessed by on-site visual NCSHP enforcement personnel who would focus on users having a disabled/inoperative transponder or a current HOV registration (assuming all are registered users) and vehicles without a valid transponder when the system is capable of only identifying and handling single-occupant vehicle users. In this case, all violations except vehicle type are occupancy violations.
- **Vehicle Type.** Vehicle does not meet the following classification types that are allowed for HOT travel:
 - Passenger vehicles (including light trucks and vans)
 - Buses (public and privately owned) and qualified courtesy vehicle with no axle count limitation
 - Motorcycles
 - Emergency vehicles.

The two primary methods of enforcing the above violations can be categorized as automated and manual. For occupancy violations, the I-77 HOT Lanes Enforcement Plan will describe and evaluate alternative automated methods for detecting and enforcing occupancy violations. However, there is no field-proven, cost-effective automated means to accurately determine occupancy violations within vehicles. For all operating HOT lane facilities within the United States, vehicle type violations rely exclusively on manual on-site enforcement, so no alternative analysis is warranted. Although the last violation type listed applies only when the system is capable of identifying all authorized users, the advantages and disadvantages of manual and automated enforcement for this violation type merits analysis. Time-tested, field-proven, automated enforcement method for unauthorized facility users (i.e., violators) involves image capture of license plate numbers by overhead mounted cameras. Image files and associated transaction records are transmitted to a violation processing site where optical character recognition is used in conjunction with manual review, confirmation and plate number extraction (when needed). Pursuant to the terms of an agreement, license plate numbers could be sent to the NCSHP to obtain registered vehicle ownership information, which is used to mail a citation to the registered owner. For the purposes of the comparison below, automated enforcement is defined as license plate recognition (LPR) in which an image capture is forwarded for review.

The advantages and disadvantages of manual and automated enforcement include:

Manual Enforcement Advantages

- Presence of NCSHP at observation and enforcement areas along the I-77 HOT lanes will demonstrate to prospective single-occupant vehicle users NCDOT's strong commitment to minimizing violations and the associated degradation to operating performance.
- If the system is capable of distinguishing HOV and single-occupant vehicle users, historical violation tracking allows enforcement details to be scheduled for days and times when the incidence of violations is highest.
- Enforcement operations for the HOT lanes also eventually benefit from other projects in the region, particularly for occupancy violations.
- Presence of the NCSHP along the HOT lanes when a traffic incident occurs will minimize response time and the length of time the facility is either closed or not meeting performance objectives.
- Manual enforcement is the only means of getting the attention of habitual violators who disregard mailed citations and may drive without current vehicle registration, thereby eliminating another means of recovering all or a portion of the amount owed.

Manual Enforcement Disadvantages

- The mere presence of NCSHP at observation and enforcement areas will adversely affect traffic flow on all lanes.
- NCSHP presence will not be continuous, and if enforcement periods are not random, the probability of commuters violating during days and times when the HOT lanes are known to be without enforcement will be higher.

- When a transaction status indicator light indicates a potential violation, the anticipated NCSHP procedure of entering the traffic stream to pursue the targeted user, positioning the patrol car or motorcycle behind the suspected violator, pulling over the user on the left or right shoulder, and if on the left shoulder, either confirming and issuing a citation there or instructing a confirmed violator to pull over at a recognizable downstream enforcement area will adversely affect traffic operations and cause disruption in free-flow conditions.
- Cost increases resulting from expanded NCSHP patrol service and escalation in labor and equipment costs can be expected over the life of the I-77 facility if not supplemented by automated enforcement.
- Conducting enforcement assignments with NCSHP officers operating in tandem to reduce the impact on traffic operations will increase enforcement costs and may not represent the highest use of a limited, publicly funded resource, particularly if the number of citations issued per suspected violator pursued is low.

Automated Enforcement Advantages

- Provides continuous enforcement of unauthorized users during facility operating hours.
- Expected to significantly reduce the adverse impact to traffic operations caused by enforcement operations by at least limiting pursuit to occupancy and the expected occasional vehicle type violations.
- Assuming quality license plate image capture equipment is procured and properly installed, ongoing maintenance cost should be minimal.
- Utility of license plate image capture equipment can be maximized by using the same equipment to validate HOV users by comparing the captured license plate number extracted in near real-time by-lane level optical character recognition (OCR) and matched to a registered HOV list.
- NCDOT/NCTA will have the resources and systems to provide violation processing services at a remote location, including manual review of license plate images, NCSHP license database interface, citation issuance, payment processing and tracking, and evidence package preparation.
- Benefits from existing legislation that requires all outstanding tolls, fines and fees be paid as a condition of re-registering the vehicle used to commit multiple violations.

Automated Enforcement Disadvantages

- Delivered HOT lane enforcement system must be capable of distinguishing valid single-occupant vehicle and HOV users to simplify the license plate image capture decision to two possible states: authorized and unauthorized user.
- Additional cost incurred for violation processing services. It is common to expect all collected violation fees and fines at least cover all costs incurred by NCDOT/NCTA to operate the subsystem.
- A citation issued to an innocent party could result in a public relations catastrophe, although the probability of such an occurrence is quite small if effective quality control procedures are implemented.

- Restoration of communication loss or repair/replacement of defective in-lane equipment must wait until a period of low traffic volumes, possibly resulting in loss of violation revenue and the ability to identify valid HOV users.
- Requires provisions for handling challenges to issued citations, typically done either through an administrative hearing judge arranged by NCDOT/NCTA or through a civil court proceeding, which increases operating costs.

9.3.1 Transaction Status Indicator Light

The transaction status indicator light shown earlier in the toll zone graphic is a LED light powered from a zone controller and activated whenever a valid single-occupant vehicle or HOV transaction is recorded. This beacon is mounted on a proposed cantilever structure pole so that it is visible from upstream of the tolling zone by a NCSHP officer in a patrol car or motorcycle. The duration of the light activation is configurable with a default value, such as two seconds. The patrol officer can use this beacon to determine potential violators corresponding to when no light activation occurs, pending confirmation of the occupants. Since the proposed concept is for HOVs to have a transponder, a transaction indicator beacon will be required to display two distinct light colors or shapes corresponding to either a single-occupant vehicle or HOV status. A single LED display capable of displaying two distinct colors can also provide the required functionality.

It has been observed that daily police activity is not necessary to keep HOT lane violations to an acceptable level; a program of varied frequency and level of effort has been found to be just as effective. Too much enforcement will degrade the operating performance of a HOT lane facility while too little will result in customer dissatisfaction and erosion in confidence in the facility. However, the presence of an officer's vehicle in the field, even without actively pursuing violators can be an effective deterrent.

Figure 9-1: Transaction Status Indicator Light



9.4 Violation Enforcement System

Violations in the HOT lanes mean any moving or civil infraction that violates North Carolina General Statutes. Violations most unique to the operation and management of HOT lanes include:

- Toll evasion
- Occupancy infractions
- Buffer crossing

Other moving violations are typically dealt with in a manner similar to any other lane on the freeway system.

9.4.1 Toll Evasion

Toll evasion enforcement involves the process of differentiating who has paid and who has violated the I-77 HOT lanes transponder presence/active account requirements. The chosen system is the Violation Enforcement System (VES) for toll evasion¹.

The VES will require:

- Mandatory registration of all HOT lane users
- Occupancy self-declaration transponders
- VES cameras and lights installed at toll gantries, oriented to capturing images of rear license plates
- LPR for license plate capture images. This system includes image capture, processing, and OCR for processing by the toll integrator.
- On-board mobile tag and account readers for police, if the selected technology can be workable to the satisfaction of NCSHP (system integrator functional requirements are worth including this option).

As a customer travels through the toll zone, the lane controller will verify that the vehicle is equipped with an active transponder and account. If no tag is detected, the license plate will be captured. Any vehicle without an active account will receive a violation notice sent to the registered owner of the vehicle. If the vehicle is registered to a valid account, the LPR will treat the vehicle, be it HOV or single-occupant vehicle, as a single-occupant vehicle and charge the associated toll. HOV vehicles who are charged in this manner may initiate a request to the CSC for a refund; a back-office correction can be made and the user will be assisted in replacing his transponder.

¹ Current transponders have a track record of working well for electronic toll applications. However, some tags do not have write capabilities, so there is no information on the tag for instant enforcement verification purposes. The current generation of transponders used by some states does not provide any means of determining or declaring vehicle occupancy. Adopting a transponder with switching capabilities will help users self declare. While current technology can be applied to promote a high level of toll evasion enforcement reliability, both buffer crossing and occupancy enforcement must be performed in the field manually by NCSHP under contract.

The VES system will reduce NCSHP's role by eliminating the need for them to provide toll enforcement. To augment the VES system, NCDOT/NCTA will monitor, test, and adopt automated vehicle occupancy verification (AVOV) systems to reduce enforcement presence and exposure upon such a time that the technology has been verified and accepted for general practice.

9.4.2 Occupancy Infractions

There are currently no new or emerging technologies that can be adapted on HOT lanes to replace on-site enforcement of vehicle occupancy. By introducing switchable transponders and LPR, NCSHP will be able to increase their focus on occupancy enforcement since they will not need to focus on toll evasion. Self-declared HOV vehicles will signal via a beacon above the toll gantry; the beacon will allow NCSHP personnel to identify self-declared HOVs, for which they will then be able to visually verify the occupancy.

9.4.3 Buffer Crossing

A common moving offense is buffer crossing, where access to the HOT lane is restricted through the use of double-solid lines. Buffer crossing will rely on on-site enforcement presence. Access to and from the HOT lane will be designated, signed and marked. The requirements for use will be posted in vicinity of all access locations. Buffer crossing monitoring may be performed from stationary or roving patrols, and apprehension will be performed on the right side shoulder or off the freeway at the discretion of the officer.

9.5 Routine Incident Management

The Federal Highway Administration (FHWA) *Guide for High-Occupancy Toll (HOT) Lane Development* provides general guidance for incident management within express lane facilities, and established protocols for most regional TMCs override any specific requirements unique to HOT lanes. In order to maintain travel time reliability, honor the payment contract with customers, and improve safety due to arbitrary merging, the Guide strongly recommends that HOT lanes be equipped with incident surveillance and detection equipment, monitored by observant (and preferably dedicated) staff at all times. Staff must be trained and experienced in incident response with drills and exercises to improve responsiveness and safety. Because the MRTMC is already established, there is little that the I-77 HOV-to-HOT lanes conversion project will contribute to established procedures.

In addition to improvements in facility communications infrastructure, the tolling system provides an opportunity to enhance incident management monitoring capabilities along I-77. On I-15 in San Diego, traffic detection, surveillance, and communications originally developed for traffic management and toll collection were eventually integrated into the facility's overall incident management system. This equipment can be used both for HOT lanes management – such as use of toll collection equipment as travel time probe sensors – or for general purpose lane incident management – such as displaying incident-related messages and diversions to motorists on toll-signal dynamic messaging signage (DMS).

As the availability of adequate resources (staffing, equipment, and communications) may be lacking for near-term deployment along I-77, the Operations Plan assumes that improvements to bandwidth and video sharing will be available for subsequent regional HOT lanes network deployment. This allows for differential approaches to the conduct of

incident management. Regardless of the implementation or phasing approach, the following should guide routine incident management:

- **Response time threshold.** Other communities have established thresholds for express lane incident response times. Florida's I-95 performance metric of two minutes response time to incidents may not be feasible for I-77; however, responding to incidents within the toll change window of five minutes is desirable and realistic. The objective for this first project is a five-minute response time to incidents upon detection, if different from established MRTMC objectives.
- **Expanding on-site response capability.** Achieving this response time may involve an expansion of on-site service patrol role, coverage and number of dedicated units. This expanded function could be funded through I-77 HOT lane revenues. Alternately, some of the regional NCSHP fleet could be dedicated only during peak demand hours to I-77. A separate dedicated patrol could perform this function on a roving basis under a third party operation and maintenance contract.
- **Communication links and protocols.** A rapid response time will rely upon field and back-office communication systems between the MRTMC, system operators, and the responding entities. The approach with an integrated functional staff role for express lane incident response housed within the MRTMC, will accomplish this goal.
- **Performance monitoring.** Regional response objectives need to be reviewed for applicability to routine incidents on I-77 HOT lanes.

9.6 Incident Management for Major Events

A major event in this context is closure of the I-77 HOT lanes or routing of all traffic into the HOT lanes. The process of diverting traffic from general purpose lanes into and out of the HOT lanes in incident situations is not without peril to their success. The HOT lanes are intended to provide a premium level of service – represented through travel time savings over adjacent general purpose lanes. From one perspective, this business model is dependent upon either recurring or non-recurring congestion in general purpose lanes. Efforts to minimize the effect of incidents upon general purpose lane users may have the effect of also minimizing the travel time incentive for carpooling, vanpooling, riding the bus, or paying a toll. Major events may negatively affect the volume of eligible HOT lane users, exacerbating the facility use. Determining the appropriate circumstances and times to divert general purpose traffic will be dependent, to an extent, upon being able to determine the benefits and impacts associated with traffic diversion. Furthermore, existing incident-response protocols could block the HOT lane in order to address a general purpose lane incident. This practice not only affects HOT lane closures but also the removal of diversion scenarios.

Because limited research has been conducted on this issue, no national guidance has been adopted. The limited research performed to date has determined that, except in the most extreme general-purpose lane incident circumstances, buffer-separated HOT lanes provide too many challenges to articulate a specific process for approving diversion applications. In the case of a major incident on the general purpose lanes, the NCSHP will determine if special use of the adjacent HOT lane is needed, based upon anticipated severity of incident, duration of incident, and lane blockage requirements to address the incident. NCSHP will communicate this need to the MRTMC, and determine the appropriate use of the lane –

maintain I-77 HOT lane operations, close it, or open it as a bypass for the general purpose traffic. When a minimum of two general purpose lanes are open to traffic, the HOT lane should resume normal operations. The MRTMC is charged with communicating NCSHP's need to the tolling integrator, who will make the necessary adjustments to toll collection on the facility, broadcasting tolls and addressing other user information on DMS in the vicinity of the affected segment.

Guiding principles include:

- The MRTMC operator will have responsibility over I-77 HOT lane closures and use during a designated major incident.
- The HOT lane tolling integrator will be in contact with the MRTMC throughout the closure process. The MRTMC will promptly inform the tolling integrator of any status changes.
- The tolling integrator will, in turn, be responsible for addressing communication to toll patrons, adjusting charges and/or changing toll rates in the affected segment. The tolling integrator will have responsibility for advising motorists of the closure at other upstream access locations along the HOT lanes, and or closure of access locations if deemed appropriate.
- The MRTMC will be responsible for handling all external communication to media outlets (same for any other incident) and will be responsible for any messages displayed to general purpose traffic in the vicinity of an incident or regionally at major junctions and decision points.

9.7 Special Events

I-77 HOT lanes may be opened to all traffic for special events, as is sometimes performed in other areas on HOV lanes. Whenever this occurs, requisite DMS signing approaching lane entrances will display the lane and toll status if all vehicles are allowed to use the HOT lanes.

Guiding principles include:

- Regular monitoring of the disposition of special events will be undertaken by NCDOT/NCTA and partner agencies at regular intervals to improve any gaps in communication and to clarify functions aimed at improving performance and safe incident handling.
- Road work and related construction or repair activity, if emergency in nature, will follow the same principles and points of contact as outlined above. Otherwise scheduled closures involving I-77 HOT lanes or general purpose lanes will be handled through routine traffic management protocols and not constitute a major event by definition.

10.0 IMPLEMENTATION PARAMETERS

10.1 Conversion of HOV Facility and Phasing Plan

While a wide variety of issues affect how the current operation is phased to include tolling, the specific transition plan will depend on which Build option is selected. As a minimum, conversion of the existing lanes with tolling will need to account for how the transition can take place without adversely affecting carpools and transit riders. Construction and lane closures may need to occur outside the peak commute hours.

If the transition plan is to include extension of the current HOV project, then tolling of the current project should probably hinge on the date an extension is ready to be opened, so that the entire project opens at one time. Otherwise, tolled traffic will be required to exit the lane treatment prior to its ultimate terminus. The transition plan would need to account for a testing period for both transponders and tolling equipment, typically 90 days or more. If this project precedes the region's first toll facility, a much higher level of advertising and awareness needs to be planned for setting up transponder accounts and testing back office functions. Desirably, conversion could take place after the opening of the Monroe Connector/Bypass, so staffing which is already in place could assist in handling administration associated with I-77 HOV-to-HOT facility conversion.

Different impacts associated with ingress/egress zones and project termini are associated with each alternative. These will need to be evaluated once a specific plan is selected for staging improvements.

10.2 Delivery Options

A wide range of project delivery options exist for conversion and extension of the I-77 HOT lanes. Delivery options already practiced in North Carolina include:

- Traditional design-bid-build;
- Design-build;
- Third party public/private partnerships (PPP) in which design, delivery and maintenance are contracted out with a defined operating or franchise period;
- Variations of the above affecting financial options and payments.

Unless financial outcomes suggest substantial positive benefits relative to costs and revenue, a PPP option for a single corridor would not appear to have enough merit to draw interest. Of the other approaches, no one delivery option appears appropriate for all of the modifications and improvements scoped in this feasibility study. For example, it is highly likely that the most competitive response for implementation involves a hybrid delivery approach in which the civil works are contracted either traditionally or by design-build, but the tolling systems integrator function is separately procured since this role may extend for several or many years into the future in a design-build-operate-maintain (DBOM) agreement. The rationale for DBOM relates to the different skill-sets associated with tolling system integration that may exist within NCDOT/NCTA. Further discussions with these groups should occur in order to settle on a best approach for tolling system support.

10.3 Future Expansion

The work performed under Task Order No. 2, in the examination of both design and operation principles outlined in this Operations Plan, included the following assumptions regarding system expansion:

- HOT lanes will eventually be extended further along the I-77 corridor so transitions and merge lanes on either end will be designated as future HOT lanes on signs and in operation and funding agreements.
- Other turnpikes, toll roads and HOT lanes may become operational in the greater Charlotte region, consistent with the recommendations of the Charlotte Regional *Fast Lanes* Study and projects included in adopted long-range transportation plans within the region.
- The capability to distinguish between carpools with two or more occupants and vehicles with three or more persons could become an evolutionary requirement of the tolling system and transponder technology.